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DOMINION OF CANADA, DEPARTMENT OF AGRICULTURE

The Chemical Composition of Native Forage Plants of Southern Alberta and Saskatchewan in Relation to Grazing Practices

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Experimental Farms Service

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S. E. Clarke and E. W. Tisdale

INTRODUCTION

The livestock industry constitutes a branch of agriculture of steadily increasing importance in Western Canada. In 1944 the livestock population of the three Prairie Provinces of Manitoba, Saskatchewan and Alberta included 1,712,800 horses, 4,621,000 cattle and 1,873,150 sheep. While the number of horses has decreased slightly, the numbers of cattle and sheep show a substantial increase over those of previous years. The bulk of the forage eaten by these animals is obtained from the native pasture lands of the area, which have been estimated to occupy at least forty million acres. The importance of securing proper utilization of these grazing lands and of providing adequate nutrition for the livestock population has become more fully realized in recent years.

Scientific studies of native pasture lands in Western Canada are of fairly recent origin. In 1927 the Dominion Range Experiment Station, the first institution of its kind in Canada, was established near Manyberries, in southeastern Alberta. At this station studies of shortgrass prairie vegetation and of the management of range livestock have been conducted. More recently, a program of pasture surveys and research covering a greater variety of range types has been initiated at the Dominion Experimental Station at Swift Current, Saskatchewan. The results of many of these studies have been presented in two recent publications (7, 8).

In addition to the projects reported in these publications, an investigation of the chemical composition of the native vegetation was started early in the course of the range studies at the Manyberries Station. It was realized that the chemical composition of the native herbage may have an important bearing on such matters as the value of various pasture types during different seasons of the year, the gains in weight made by livestock during different parts of the growing season, and the most profitable time to market range livestock. The extent to which supplementary feeding is needed and the time of the year when it is necessary may be revealed also by analyses of the pasture vegetation. Studies in other pasture areas of the world had shown that great differences may occur in the nutritive value of different plant species, of a single species in different growth stages, or of any one species grown under different conditions of soil or climate. Some of these researches had revealed the presence of marked deficiencies in the composition of pasture forage which interfered seriously with the nutrition of livestock. It was evident that the nutritive value of the native pasture species as well as their palatability, productivity and reaction to grazing would have to be determined before range management plans aimed at maximum production of livestock could be developed.

Chemical analysis, while not capable of giving as full information regarding nutritive value as would actual digestibility trials, was adopted as the only practicable means of securing an estimate of the feeding value of the large number of native forage species occurring in the area. Deficiencies of essential

elements and the relative composition of different forages can be revealed by chemical analysis. Where the chemical composition of a species is known, an estimate of its actual nutritive value often may be obtained from the results of feeding trials which have been conducted with forages of similar composition.

During the period 1927 to 1940, approximately one thousand samples of native vegetation were collected and analysed. These included all the more important species of the prairies as well as considerable material from other range areas including the Great Sandhills, Cypress Hills and foothills of the Rocky Mountains.

Only a few preliminary data have been published previously (5,6). The results of the entire study of the chemical composition of native pasture species in relation to grazing practices and livestock production in southern Saskatchewan and Alberta are presented in the present publication. Further studies of the composition of prairie, sandhill and forest forages as well as more intensive investigations of the effects of climate and soil on the chemical constituents of pasture herbage are in progress.

DESCRIPTION OF THE AREA

Location and Extent

The area included in this study is indicated in Fig. 1. Roughly, it comprises a tract extending from the southeastern corner of Saskatchewan on the east to the foothills of the Rocky Mountains on the west. The boundary between the United States and Canada constitutes the southern border of the area, while its northern limits lie along a line passing close to the towns of Qu'Appelle and Marsden in Saskatchewan and Vermilion and Stettler in Alberta. This region is nearly the same as that occupied by the Brown and Dark Brown soil zones in Saskatchewan and Alberta, with the addition of certain areas in the Cypress Hills and Rocky Mountain Foothills. It is estimated that there are close to thirty million acres of native pasture land in this region.

Topography

The greater part of the area is occupied by a level to undulating plain, which rises gradually from the east to its western limit at the foothills of the Rockies. The continuity of the plain is broken by a number of hilly areas, of which the Cypress Hills is the most prominent. In addition, there are areas of rough topography in the Great Sand Hills and other localities where sand dune formation has occurred. Broad valleys from 100 to 500 feet deep are typical features. These include the valleys of the North and South Saskatchewan, and of the Bow, Red Deer and Milk rivers. The average altitude of the plain varies from 1,500 feet above sea level along the eastern edge of the area to 3,500 feet and over at the western limits. The Cypress Hills reach an altitude of nearly 5,000 feet at their highest point, but none of the other ranges is so prominent.

Climate

Moisture is the limiting factor for plant growth over most of the area. Precipitation is low in amount and irregular in distribution, particularly in the southwest and south central portions of the region. Other features of the climate include a high rate of evaporation, great extremes of temperature, high and frequent winds and abundant sunshine. In the Rocky Mountain Foothills and the Cypress Hills these conditions are modified considerably due to greater altitude. Moisture conditions are more favourable, but the frost-free season is shorter in these regions.

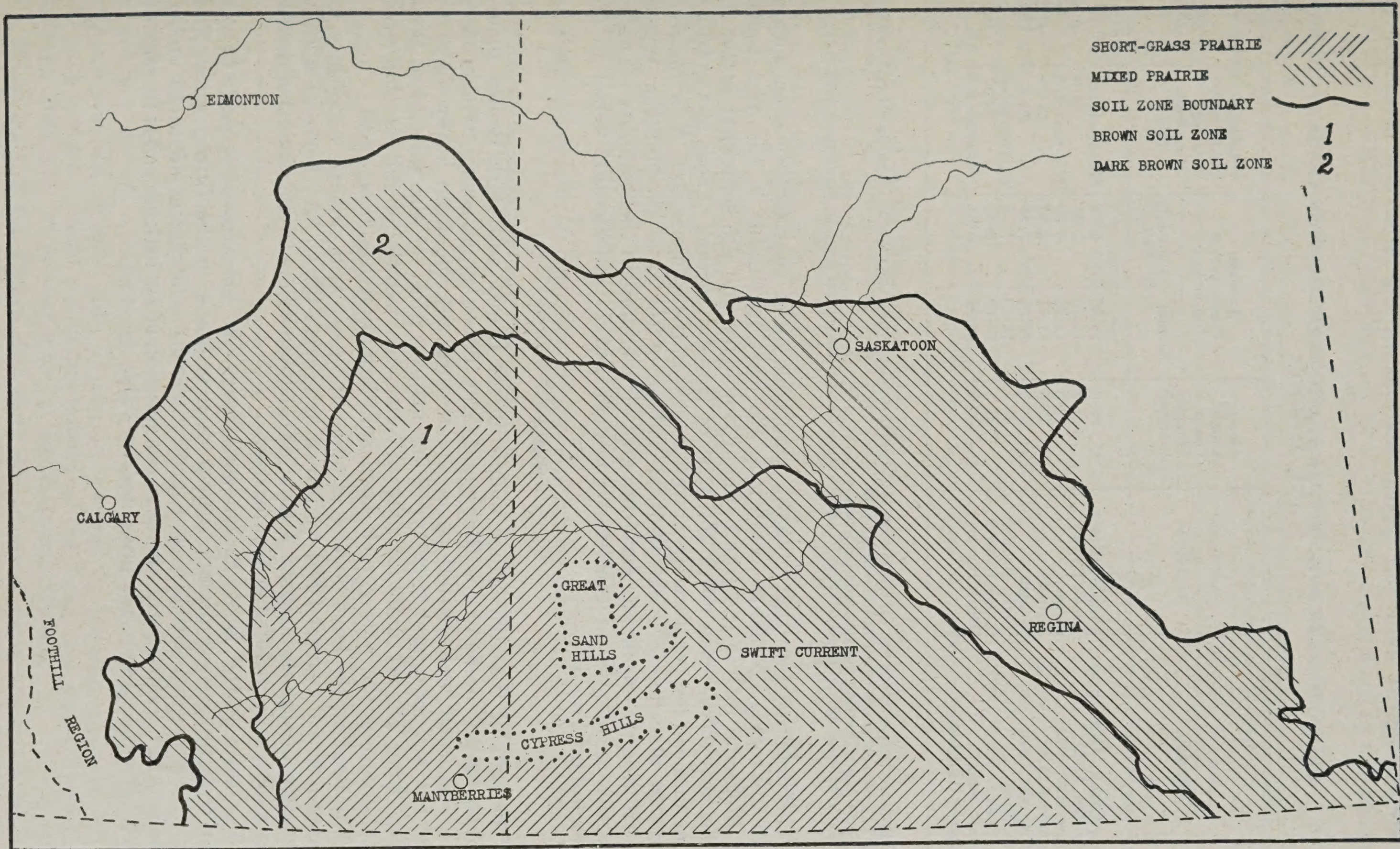

FIGURE 1.—Sketch map of southern Alberta and Saskatchewan showing principal vegetation and soil zones in the area included in the study.

Meteorological data for typical stations in the area are presented in Table 1.

TABLE 1.—CLIMATIC DATA FOR TYPICAL STATIONS IN SOUTHERN SASKATCHEWAN AND ALBERTA

Station	Soil Zone	Mean Annual Temp. in Degrees Fahrenheit	Average Precipitation in inches		Average Evaporation in Ins. May-Sept. Incl.	P/E Ratio[2]
			Annual	April-July Incl.		
Pincher Creek, Alta	Shallow Black	39·0	19·93	9·74	Not recorded	
Lethbridge, Alta[1]	Dark Brown	41·2	15·76	7·82	24·6	0·64
Medicine Hat, Alta	Brown	42·0	12·70	6·70	Not recorded	
Manyberries, Alta[1]	Brown	40·5	11·71	6·30	33·17	0·35
Swift Current, Sask.[1]	Brown	38·5	13·50	7·38	29·8	0·45
Regina, Sask	Dark Brown	33·2	14·10	7·74	Not recorded	
Scott, Sask.[1]	Dark Brown	33·5	13·69	6·88	20.52	0·66
Klintonel, Sask (Cypress Hills region)	Dark Brown	36·0	16·61	8·61	Not recorded	

The Manyberries data are for the period 1929-1942 inclusive, while the records from the other localities are for 21 years or more, up to and including 1942.

[1] Data from Dominion Experimental Stations.

[2] Ratio of total annual precipitation to evaporation during the period May to September inclusive.

The data indicate that climatic conditions differ considerably even within the plains region. Moisture conditions are least favourable in the area south from Medicine Hat to the International Boundary and are somewhat better in the districts to the east, north and west of this dry section. There is a gradual decline in mean temperatures from west to east in the whole region. A favourable feature of the climate is the high percentage of the total precipitation which occurs during the spring and early summer. The climate of the Manyberries area, of particular interest in this study, is described in considerable detail in an earlier publication (8).

Soils

The soils of the area belong mainly in the Brown and Dark Brown zones, although limited areas of the Black and Grey Forest types occur. Within each zone there occur wide variations in soil texture, ranging from heavy clays to sands, but the most prevalent types are loams. Most of the soils have been derived from glacial material, but in some the mantle of till is thin and the influence of the native rock upon soil formation has been great.

The Brown soils have developed under the most arid climatic conditions in the area and are characterized by brown or greyish-brown "A" horizons with a low content of organic matter. A layer of calcium carbonate accumulation occurs at an average depth of one foot or less.

The soils of the Dark Brown zone have "A" horizons of a dark brown colour containing more organic matter than is found in the Brown soils. The layer of lime accumulation is at a greater depth, occurring at 15 to 18 inches on the average. Data on the chemical composition of typical soil series in each of the two principal zones are presented in Table 2.

TABLE 2.—CHEMICAL COMPOSITION OF TYPICAL PRAIRIE SOILS IN SOUTHERN SASKATCHEWAN

Data from Saskatchewan Soil Survey Report No. 10 (38)

Soil Zone and Series	Texture	Chemical Composition in Per Cent				pH
		Nitrogen	Phosphorus	Calcium	Potassium	
Brown Zone—						
Sceptre	Heavy clay	0·22	0·06	1·03	1·70	8·2
Haverhill	Loam	0·20	0·06	0·44	1·60	7·9
Hatton	Fine sandy loam	0·16	0·04	0·37	1·40	
Echo[1]	Clay loam	0·15	0·03	0·24	1·60	6·5
Dark Brown—						
Weyburn	Loam	0·26	0·07	0·65	1·80	
Asquith	Fine sandy loam	0·19	0·05	0·70	1·40	

All data based on analysis of the surface foot of soil.

[1] The Echo series is a solonetz type developed in areas where the influence of pre-glacial material is strong.

It will be noted that these soils are all fairly well supplied with lime and potassium, but the nitrogen and phosphorus contents are inclined to be low, particularly in the coarser-textured series and the solonetz soils of the Brown zone. Most of the figures in Table 2 are applicable throughout the extent of their respective zones in both Saskatchewan and Alberta. However, data from soil surveys in southeastern Alberta (50,51) indicate that the nitrogen content in this area is generally lower than shown above. In the Brown soils of this region the average nitrogen content is approximately 0·135 per cent while that of the Dark Brown soils is about 0·200 per cent.

The composition of soils at the Manyberries Range Station is of particular interest in this study since so many of the plant samples were obtained in this locality. Data for typical soils in the area are presented in Table 3.

TABLE 3.—CHEMICAL COMPOSITION OF THE SURFACE FOOT OF SOILS AT THE MANYBERRIES RANGE STATION

Type	Texture	Chemical Composition in Per Cent					pH
		Nitrogen (Total)	Phosphorus		Potassium		
			Total	Avail.	Total	Avail.	
Upland	Sandy loam	0·150	0·063	0·020	0·473	0·028	7·7
Alluvial flat	Silty loam	0·095	0·062	0·010	0·651	0·021	8·2
Blowout area	Silty clay loam	0·110	0·051	0·012	0·540	0·016	7·9

The data indicate that the sandy loam upland soils at the Manyberries Station are fairly similar in composition to those of comparable texture in the Brown zone generally. The alluvial soils are low in nitrogen and available phosphorus. The soils of the blowout areas are low in fertility also, being low in nitrogen and in available phosphorus and potassium. Blowout is the term used to describe shallow pits formed by erosion of varying amounts of the "A" soil horizon. These are characteristic of the Echo soil series in southern Saskatchewan and of similar soils in southeastern Alberta.

While soils of the Brown and Dark Brown zones occupy most of the area covered in this study, other types exist in the Cypress Hills and foothills of the Rockies. Shallow Black, Normal Black and Grey Forest soils occur in these

areas, the first named being the lowest in the altitudinal series. Data on the chemical composition of some typical foothill soils are presented in Table 4. The figures are for the average composition of all samples within each zone, regardless of texture. The data are calculated on the surface foot of soil.

TABLE 4.—CHEMICAL COMPOSITION OF TYPICAL ROCKY MOUNTAIN FOOTHILL SOILS

Data from Alberta Soil Survey Reports (50, 52)

Zone	Composition in Per Cent		pH
	Nitrogen	Phosphorus	
Dark Brown	0·200	0·067	6·8
Shallow Black	0·280	0·077	7·0
Normal Black	0·520	0·100	6·0
Grey Forest	0·120	0·042	5·4

Both nitrogen and total phosphorus increase from the Dark Brown to the Normal Black soils. Although the total phosphorus content of the Normal Black soils is relatively high, the percentage of the total which is available is much lower than in the Shallow Black, Dark Brown or Brown zones. The Grey Forest soils are leached heavily and as a result are low in organic matter, nitrogen and phosphorus.

The limited data available for the Black and Grey Forest soils in the Cypress Hills indicate that they are similar in composition to those of Table 4.

Native Vegetation

The vegetation of the area consists mainly of grassland, although shrub and forest communities occur in the sandhill regions, in the Cypress Hills and in the Rocky Mountain Foothills. Brief descriptions of the main plant associations are presented in the following section. For more detailed information the reader is referred to other publications (6, 7, 8) by the authors and co-workers, also to a recent paper by Moss (33).

The grasslands include three main types, namely Shortgrass Prairie, Mixed Prairie and Submontane Prairie.

Shortgrass Prairie

This association occurs under the most arid conditions found in the study area, being associated with the drier portion of the Brown Soil zone. The approximate extent of the area occupied by this type of vegetation is indicated in Figure 1. There is a broad transition zone between the Shortgrass and Mixed Prairie which makes the establishment of boundaries very difficult. Plant growth is generally shorter in the Shortgrass Prairie than in the other two types of grassland and productivity is lower.

The most abundant species is blue grama grass (*Bouteloua gracilis*). Other dominants in order of importance are common speargrass (*Stipa comata*), western wheatgrass (*Agropyron Smithii*), Junegrass (*Koeleria cristata*) and dwarf bluegrass (*Poa secunda*). Involute-leaved sedge (*C. Eleocharis*) is abundant while niggerwool (*C. filifolia*) is of frequent occurrence. Common broad-leaved plants include pasture sage (*Artemisia frigida*), dwarf phlox (*Phlox Hoodii*), broom weed (*Gutierrezia diversifolia*), winter fat (*Eurotia lanata*), salt sage (*Atriplex Nuttallii*) and sagebrush (*Artemisia cana*). Cactus (*Opuntia polyacantha*) is a characteristic species of this zone. Little clubmoss (*Selaginella densa*) is abundant over much of the area, but because of its

low water and nutrient requirements it does not exert much influence in the association. The five grasses and two sedges listed above compose about 80 per cent of the total plant cover, little clubmoss excluded.

Mixed Prairie

This type is associated with better moisture conditions than those found in the Shortgrass Prairie, and is the dominant association in the Dark Brown Soil zone and the moister portions of the Brown Soil zone. The more favourable climatic conditions are reflected in the development of a richer flora and taller growth than that occurring in the shortgrass type.

The principal species are short-awned porcupine grass (*Stipa spartea* var. *curtiseta*), common speargrass, northern wheatgrass (*Agropyron dasystachyum*), western wheatgrass, Junegrass, grama grass, involute-leaved sedge and sun-loving sedge (*Carex heliophila*). Green speargrass (*Stipa viridula*) and rough fescue (*Festuca scabrella*) are common in favoured locations. Pasture sage and broom weed are the principal forbs.

It is evident that most of the dominants of the Shortgrass zone extend into the Mixed Prairie, but that they are supplemented and often exceeded in abundance by plants not common in the former type.

Shrubs are more common than in the Shortgrass zone and include a greater variety of species. The principal forms are wild roses (*Rosa* spp.), snowberry (*Symphoricarpos occidentalis*) and wolf willow (*Elaeagnus commutata*). Trees, mainly aspen poplar (*Populus tremuloides*) and willows (*Salix* spp.) occur in spots where moisture conditions are better than average.

Submontane Prairie

This association occurs adjacent to the Mixed Prairie at higher altitudes in the Cypress Hills and Rocky Mountain Foothills. It is associated with cooler

FIGURE 2.—Typical stand of mixed prairie. Speargrasses, Junegrass and wheatgrasses are the principal species. Note patches of the shrub, Western snowberry, in the background.

and slightly moister conditions than those under which Mixed Prairie is developed. It occurs on soils of the Black zone and may develop on Shallow Black soils also (33).

FIGURE 3.—Range types in the Rocky Mountain Foothills. Submontane prairie in foreground with forest range on higher ground close to the mountains. Willows are common in lower-lying parts of the grassland.

The principal species is rough fescue, while Idaho fescue (*Festuca idahoensis*), wild oatgrass (*Danthonia intermedia*) and Parry's oatgrass (*D. Parryi*) often are abundant. Junegrass, northern wheatgrass, awned wheatgrass (*Agropyron trachycaulum* var. *unilaterale*), short-awned porcupine grass and Hooker's oatgrass (*Avena Hookeri*) are common. Forbs are relatively abundant and include species of hedysarum, lupine and wild geranium. The principal shrubs are shrubby cinquefoil (*Dasiphora fruticosa*), wild roses and snowberry. Aspen poplar and willows occur in low spots and on sheltered slopes.

Vegetation of Sandhill Areas

In the Great Sandhills and other smaller areas where sand dune formation has occurred there is considerable variation in plant cover, mainly in response to differences in soil moisture conditions.

On areas where the water-table is at a considerable depth, the vegetation consists mainly of grassland. Many of the species found in the prairie associations, such as common speargrass, grama grass, Junegrass, involute-leaved sedge, pasture sage and smooth goldenrod (*Solidago glaberrima*) are abundant. In addition, several plants occur which are characteristic of sandy soils. These include sandgrass (*Calamovilfa longifolia*), sand dropseed (*Sporobolus cryptandrus*), Indian ricegrass (*Oryzopsis hymenoidos*) and Canada wild rye (*Elymus canadensis*). Sand dock (*Rumex venosus*), lance-leafed psoralea (*Psoralidium lanceolatum*) and Fendler's cryptanthe (*Cryptantha Fendleri*) are characteristic sandhill forbs.

Where moisture conditions are more favourable, a shrub association develops. The principal species are Macoun's rose (*Rosa Macounii*), chokecherry (*Prunus melanocarpa*), wolf willow, sagebrush, snowberry and creeping juniper (*Sabina horizontalis*). The herbaceous cover consists of a mixture of forbs and grasses, including pasture sage, smooth goldenrod, sand dropseed, sandgrass, Canada wild rye and involute-leaved sedge.

FIGURE 4.—Typical sandhill vegetation. Common speargrass and sandgrass make up the bulk of the grass cover shown here, while chokecherry (dark in photo) and willows (lighter coloured) are the principal shrubs.

Under still more favourable moisture conditions, trees and tall shrubs occur. The principal species are aspen poplar, balm-of-Gilead (*Populus tacamahacca* var. *candicans*), several species of willow including Bebb's willow (*Salix Bebbiana*) and sandbar willow (*S. interior*), river birch (*Betula fontinalis*) and chokecherry. This tree growth may occur as scattered clumps in depressions among shrubs or grassland or may form extensive stands in areas where climatic conditions are more favourable.

Forest Vegetation

Tree growth constitutes an important part of the native vegetation in the Cypress Hills and in the Rocky Mountain Foothills. In both areas two main types of forest cover occur, namely, the aspen grove association along the upper border of the grassland, and coniferous forest at higher altitudes.

The aspen grove type consists of clumps of trees, mainly aspen poplar, intermingled with grassland of the Submontane Prairie association. Willows and black poplar (*Populus tacamahacca*) occur in moist spots within this type. Shrubs include wild roses, snowberry and saskatoon (*Amelanchier alnifolia*). Common herbaceous species include awned wheatgrass, fringed brome (*Bromus ciliatus*), mountain brome (*B. marginatus*), pea-vine (*Lathyrus ochroleucus*) and American vetch (*Vicia americana*).

The coniferous forest is dominated mainly by white spruce (*Picea glauca*) and lodgepole pine (*Pinus contorta* var. *latifolia*). Spruce is the principal climax species, but as a result of repeated fires, large areas are occupied at present by nearly pure stands of pine. Other common trees include aspen poplar and willows. Shrubs include low buffalo berry (*Shepherdia canadensis*), dwarf spiraea (*Spiraea lucida*) and wild rose. The herbaceous cover is dominated usually by pinegrass (*Calamagrostis rubescens*), bearberry (*Arctostaphylos Uva-ursi*) and twinflower (*Linnaea americana*). Species which are common, particularly where the tree cover is fairly open, include awned wheatgrass, fringed brome, pea-vine and American vetch.

The type of coniferous forest described above includes both the Mixedwood and Foothills sections of the Boreal Forest as described by Halliday (22). The aspen grove type corresponds to the section of the same name under his Boreal Forest classification. The Subalpine Forest type which occurs at higher elevation in the foothills was not included in the present study.

METHODS OF STUDY

In collecting, pure samples of each species in one growth stage were obtained usually, composite sampling being used only in special cases. Collections were made according to stages of development rather than by chronological dates. Differences in composition among species and among different growth stages of any one species rendered this procedure necessary in order to obtain data which could be applied to actual range conditions. Samples were taken in such a manner as to simulate actual grazing as closely as possible. Highly palatable grasses were clipped closely, while only the current year's growth of shrubby species was taken.

Samples at the Manyberries Station were taken from sites selected as representative for the species, and the same sites were used each season. When collecting in other localities it was not always possible to establish definite sites, but every effort was made to obtain samples from representative areas. Within each site, the clippings composing any one sample were taken at random over the area and then composited. Clipping of the mature growth on sites in late fall or very early spring was found to facilitate greatly the task of obtaining pure samples of current growth during the following season.

All material was air-dried as quickly as possible, and forwarded to the Division of Chemistry, Science Service, Ottawa, for chemical analysis. The standard feeding stuffs determination of crude protein, crude fibre, ether extract, total ash and nitrogen-free extract was made. In addition, the phosphorus and calcium content was determined for all samples collected after **1928**. Silica content was determined for a limited number of samples.

REVIEW OF LITERATURE

During the past two decades particularly, numerous studies have been reported dealing with the chemical composition and nutritive value of pasture herbage in many parts of the world. In general these researches may be divided into two main groups, first those dealing with highly productive pastures, often sown to cultivated species in relatively humid areas, and second, those dealing with grazing lands of relatively low productivity in semi-arid and arid areas where the bulk of the forage consists of native species. The present study belongs to the second group.

Studies of the chemical composition and nutritive value of native forages and of deficiencies occurring in them have been numerous in the Western United States, South Africa and Australia. Reviews of the literature have been published by Gordon and Sampson (19), Watkins (46) and others. No attempt

will be made here to mention more than a few studies which have a bearing on the present work. Other references dealing with particular phases of the problem will be introduced in the sections to which they are pertinent.

A number of studies of the changes in chemical composition occurring during the seasonal development of range forage species have been reported. Gordon and Sampson (19), found that in herbaceous plants on California ranges there was an orderly decline in the percentage of crude protein, silica-free ash, calcium, phosphorus and potassium during seasonal development. Crude fibre increased with the advance of the season. The most rapid changes in constituents occurred during the period from early leaf to full bloom.

Hopper and Nesbitt (25) in North Dakota present data for native and cultivated forages of their region which indicate that crude protein decreased with seasonal development, while crude fibre and nitrogen-free extract increased and total ash and ether extract showed no definite trend.

Stanley and Hodgson (41) found declines in protein and phosphorus and increases in nitrogen-free extract and crude fibre during the seasonal development of Arizona range grasses. Total ash and ether extract showed no definite trends.

Fraps and Fudge (18) working with range forages in East Texas found that protein and phosphorus declined regularly with seasonal development while crude fibre and nitrogen-free extract increased. Lime usually decreased but the tendency was irregular in many species.

McCall (31) found that with bluebunch fescue (*Festuca idahoensis*) in the state of Washington, seasonal trends in composition were very marked. Crude protein and phosphorus declined greatly with increasing maturity, crude fat and calcium declined to a lesser degree, while fibre increased greatly.

Deficiences of certain minerals, particularly phosphorus, have been reported for pasture areas in many parts of the world. Theiler and co-workers (44) found the phosphorus content of native pastures in South Africa to be very low, and proved that certain diseases of livestock were caused by lack of this mineral. Phosphorus deficiencies have been reported for areas in both Australia and New Zealand, while a lack of iron occurs in certain parts of the latter country. In the United States, phosphorus deficiences have been found in Florida, Minnesota, Montana (39), New Mexico (46), Texas and other states. In Canada, the native forage in parts of Manitoba (17) and the Shortgrass Prairies of southern Alberta and Saskatchewan (6, 46) has proved to be low in phosphorus.

Beneficial results from feeding supplemental minerals have been reported by many workers. The feeding of additional phosphorus, a practice pioneered in South Africa, has been found advantageous by many workers including Dutoit and co-workers (16) in South Africa, Black and co-workers (3) in Texas and Knox and Watkins (28) in New Mexico.

The relation of the digestibility and nutritive value of pasture species to their chemical composition has been studied considerably in recent years. Several workers, including Crampton (10) and Maynard (29) have pointed out discrepancies between the results of chemical analysis and actual feeding tests. These workers, along with Christensen and Hopper (9), Burkitt (4), Sotola (39, 40) and others found that the digestibility of all nutrients in pasture herbage decreases with the advance of the season and approach of maturity. The effects of seasonal changes in the quantity of the various nutrients, as revealed by chemical analysis, are thus intensified by changes in their quality. The importance of total digestible nutrients as well as of digestible protein content in cured range forage has been pointed out by Stanley and Hodgson (42).

Norman (34) and others have shown the high nutritive value of carbohydrates of young grass, including the crude fibre fraction. The importance of

lignin, as influencing the digestibility of other fractions, especially cellulose, has been stressed (10, 34). Revised methods of chemical analysis involving the determination of lignin and cellulose have been suggested for pasture forages (10, 11, 29). Preliminary tests by Crampton and Forshaw (11) in Quebec and Patton and Griseker (35) in Montana indicate the possibilities of these newer analytical methods in obtaining results more in accord with the results of actual feeding trials.

THE CHEMICAL COMPOSITION OF PRINCIPAL FORAGE SPECIES

The data obtained in this study are presented separately for the main range types of the area, including Shortgrass Prairie, Mixed Prairie, Sandhill Vegetation, Submontane Prairie and Forest. Two groups of plants not associated with any particular zone, namely meadow species and cultivated grasses are treated in additional sections. Since the majority of samples were collected in the shortgrass association, the data for this community are presented first and in greatest detail.

Shortgrass Prairie Species

Samples were collected mainly at the Manyberries Range Station although some collections were made in other parts of the Shortgrass area. In the case of dominant species, samples were obtained in each of the principal growth stages for a period of several years. The object was to obtain a detailed knowledge of the composition of these key species, including differences due to growth stage and to variations in climatic conditions from year to year. For plants of secondary importance, enough samples were secured to enable a comparison to be made with the principal species.

For the purposes of convenience in presenting the data, the forage plants of the Shortgrass Prairie are divided here into the following three groups:

(1) Principal grasses and grass-like plants

(2) Grasses and grass-like plants of secondary importance

(3) Forbs and shrubs.

Principal Grasses and Sedges

It has been found (8) that five species of grass and one sedge constitute about 80 per cent of the plant cover and 90 per cent of the forage on typical shortgrass prairie range. Due to its great importance, this group was studied in more detail than any other. A summary of the data is presented in Table 5.

TABLE 5.—CHEMICAL COMPOSITION OF PRINCIPAL GRASSES OF SHORT-GRASS PRAIRIE

Species and Growth Stage	No. of Samples	Av. Date Collected	Chemical Composition in Per Cent						
			Crude Protein	Crude Fibre	Ether Extract	Nitrogen Free Extract	Total Ash	Calcium	Phosphorus
Grama grass *(Bouteloua gracilis)*—									
Leaf	8	June 19	14·85	24·80	—[2]	....	8·94	0·459	0·188
Flower	7	July 26	9·52	30·48	1·43	50·97	7·24	0·330	0·180
Medium seed[1]	5	Aug. 14	7·46	30·94	2·03	53·15	6·42	0·357	0·147
Cured	8	Oct. 13	5·22	30·46	1·53	54·05	8·74	0·353	0·120
After winter exposure	4	Apr. 10	5·00	31·91	....	....	10·62	0·413	0·073
Common speargrass *(Stipa comata)*—									
Leaf	9	May 23	18·87	24·20	2·62	46·39	7·92	0·376	0·258
Flower	11	June 24	9·80	30·22	2·37	53·01	4·63	0·258	0·191
Medium seed	10	July 11	8·26	33·58	2·61	50·20	5·10	0·293	0·148
Cured	7	Oct. 13	4·87	33·77	2·28	51·66	7·42	0·440	0·078
After winter exposure	3	Apr. 9	3·65	35·48	1·46	52·66	6·75	0·320	0·070
Western wheatgrass *(Agropyron Smithii)*—									
Leaf	9	May 31	17·35	27·84	2·65	43·81	8·36	0·375	0·217
Flower	9	July 3	10·76	33·21	2·34	46·29	7·40	0·285	0·156
Medium seed	5	July 18	7·79	34·10	2·06	49·32	6·73	0·220	0·132
Cured	6	Oct. 20	3·80	33·50	2·05	51·09	9·56	0·381	0·060
After winter exposure	5	Apr. 12	3·58	33·81	1·26	49·75	11·60	0·462	0·046
Junegrass *(Koeleria cristata)*—									
Leaf	8	May 11	20·30	23·34	3·46	42·54	10·36	0·409	0·268
Flower	13	June 17	8·62	33·50	2·74	48·21	6·93	0·270	0·178
Medium seed	6	July 5	6·57	34·24	2·83	47·92	8·44	0·343	0·126
Cured	8	Oct. 5	4·60	35·86	1·64	48·85	9·05	0·315	0·075
After winter exposure	4	Apr. 5	4·28	35·77	0·97	50·16	8·82	0·360	0·070
Dwarf bluegrass *(Poa secunda)*—									
Leaf	5	May 10	20·27	24·69	....	....	9·68	0·332	0·336
Flower	10	May 28	10·47	33·27	2·96	47·15	6·15	0·240	0·202
Medium seed	6	July 7	5·95	35·44	3·60	48·37	6·64	0·242	0·115
Cured	4	July 11	5·24	38·38	....	....	5·14	0·230	0·076
After winter exposure	2	Apr. 3	3·10	38·26	1·20	51·36	6·08	0·250	0·050
Niggerwool *(Carex filifolia)*—									
Flower	4	Apr. 29	18·14	22·64	....	....	7·66	0·437	0·220
Medium seed	4	May 29	14·48	24·25	3·28	50·63	7·36	0·433	0·180
Cured	5	Sept. 20	6·65	29·75	3·34	50·46	9·80	0·585	0·079

The data in this and all succeeding tables are calculated on a dry matter basis unless stated otherwise.
[1] "Medium seed" equals seed in the early dough stage.
[2] Dashes indicate—No determination made.

The data indicate general similarity in the composition of the grasses, although differences do occur in the case of certain constituents in some growth stages. For example, the protein and phosphorus content of samples in the leaf stage is higher in early species such as Junegrass and dwarf bluegrass than in the late developing grama grass. This difference disappears by the time the flowering stage is reached.

Niggerwool, the one sedge included in Table 5 tends to be richer in protein, ether extract and calcium and lower in crude fibre than the grasses.

It is evident that changes in chemical composition at different growth stages were generally much greater than differences between species in the same growth stage. The percentage of most constituents changed greatly from the early leaf to the cured stage, and even in the dry forage during winter. These changes in composition due to growth development are brought out more clearly in Table 6 in which data for the grass species of Table 5 have been averaged.

TABLE 6.—AVERAGE CHEMICAL COMPOSITION OF FIVE MAIN GRASSES OF SHORT-GRASS PRAIRIE

Growth Stage	No. of Samples	Chemical Composition in Per Cent							Calcium: Phosphorus Ratio
		Crude Protein	Crude Fibre	Ether Extract	Nitrogen Free Extract	Total Ash	Calcium	Phosphorus	
Leaf	39	18·33	25·0	2·57	45·7	9·05	0·390	0·252	1·5:1
Emerging from sheath	18	13·10	29·2	2·79	47·8	7·53	0·274	0·206	1·3:1
Flower	50	9·83	32·1	2·37	49·1	6·47	0·277	0·181	1·5:1
Medium seed	36	7·21	33·7	2·64	49·7	6·66	0·291	0·134	2·2:1
Cured	33	4·85	34·5	1·87	51·7	8·37	0·337	0·084	4·0:1
After winter exposure	18	4·02	35·4	1·26	50·8	8·73	0·361	0·062	5·8:1

Comparison of these average data with those for the individual species indicates that there is a strong similarity in the changes occurring in each of the five species during growth development.

The crude protein content is highest in the leaf stage and drops sharply as growth development proceeds, reaching a minimum in the cured forage collected in the following spring.

Crude fibre varies in an opposite manner to protein, increasing with each successive growth stage. The percentage of nitrogen-free extract increases also, but to a much smaller degree.

The content of ether extract remains relatively constant during the earlier growth stages but declines when curing occurs and becomes still further reduced over winter.

The trend for phosphorus is similar to that for protein, there being a decline throughout the whole period of growth development.

The calcium content exhibits a trend different from that shown by other constituents. It is at a maximum in the leaf stage and after winter exposure and lowest during emerging and flowering. While this course is indicated clearly by the average data, it was not followed closely by all five species. In speargrass there was a decided drop in calcium content over winter, while in western wheatgrass the minimum occurred in the seed stage.

The calcium-phosphorus ratio is relatively low and constant in the earlier growth stages but increases from the time of seed production and reaches a maximum after winter exposure.

The percentage of total ash shows a seasonal curve, with the low point occurring during the flowering stage. Data for silica-free ash obtained during two years of the study show that this apparent trend is due to the silica content. Data for total and silica-free ash in three of the five major grass species are presented in Table 7.

TABLE 7.—AVERAGE ASH CONTENT OF THREE IMPORTANT SHORTGRASS PRAIRIE SPECIES[1]

Growth Stage	Composition in Per Cent		
	Total Ash	Silica	Silica-free Ash
Leaf	8·26	3·79	4·47
Flower	6·18	2·75	3·43
Medium seed	6·49	3·77	2·72
Cured	7·15	4·96	2·19

[1] The data are averages for common speargrass, grama grass and Junegrass.

It is evident that there is a steady seasonal decline in silica-free ash. Silica, which is of no value in animal nutrition, is abundant in these grasses, and its presence masks the trend of the other mineral elements when no separate determination of silica-free ash is made.

Grasses of Secondary Importance

There are several native grasses which occur commonly in the Shortgrass Prairie area but which are not sufficiently abundant to rank with the dominant species discussed previously. Some are scattered throughout the uplands, while others are localized in areas where conditions of soil moisture, salt concentration, etc., differ from those prevailing in the zone generally. These species may contribute a considerable proportion of the grazing in certain areas or at certain seasons of the year. The data for some of these forms are summarized in Table 8.

TABLE 8.—CHEMICAL COMPOSITION OF GRASSES OF SECONDARY IMPORTANCE IN SHORTGRASS PRAIRIE

Species	Stage of Growth	Av. Date Collected	No. of Samples	Chemical Composition in Per Cent				
				Crude Protein	Crude Fibre	Ether Extract	Calcium	Phosphorus
A—PLANTS OF NON-SALINE PRAIRIE—								
Plains reedgrass								
(Calamagrostis montanensis)	Leaf	May 22	2	11·90	27·96	3·56	0·261	0·187
" "	Flower	June 27	2	8·56	32·06	3·91	0·246	0·153
Prairie muhlenbergia[1]								
(Muhlenbergia cuspidata)	Leaf	May 29	2	11·30	26·32	2·65	0·390	0·166
Canby's bluegrass								
(Poa Canbyi)	Flower	June 30	2	7·30	36·50	....	0·190	0·205
B—PLANTS OF SALINE AREAS—								
Saltgrass								
(Distichlis stricta)	Leaf	June 4	5	15·10	27·01	2·68	0·248	0·194
" "	Flower	July 16	4	10·18	29·08	2·54	0·225	0·153
" "	Seed	Aug. 10	3	7·50	28·83	2·09	0·210	0·092
Wild barley[2]								
(Hordeum jubatum)	Leaf	May 24	4	23·98	26·74	3·98	0·428	0·346
" "	Flower	June 26	4	10·40	32·24	1·96	0·238	0·216
Nuttall's alkali grass								
(Puccinellia Nuttalliana)	Flower	June 28	3	10·88	31·19	....	0·213	0·217
Alkali cordgrass								
(Spartina gracilis)	Flower	July 6	2	5·90	39·54	....	0·310	0·153

[1] Occurs mainly on eroded slopes.
[2] Common on abandoned fields as well as saline areas.

Considerable differences occur among the different species, but not to any extent between the two ecological groups. Most of the plants of Table 8 contain slightly less protein and phosphorus in the leaf stage than do the grasses of Tables 5 and 6. This difference disappears largely in subsequent growth stages. The protein content of wild barley ("foxtail") in the leaf stage is actually much higher than that of the dominant upland grasses. On the other hand, prairie muhlenbergia and alkali cordgrass are inferior to the species of Table 5 in content of protein and minerals. The fat content of most plants of Table 8 is as high or higher than that of the dominant upland grasses. Determinations of total ash and nitrogen-free extract were made for a few of the secondary species. The data, not presented here, are in general agreement with those for the grasses of Table 5.

Broad-Leaved Species

While the greater part of the forage of shortgrass prairie ranges is composed of grasses and sedges, there are several broad-leaved herbs and shrubs which are of considerable value for grazing. The most important species of this group are salt sage and winter fat. Data for these two plants are presented in Table 9.

TABLE 9.—CHEMICAL COMPOSITION OF PRINCIPAL BROAD-LEAVED FORAGES OF SHORTGRASS PRAIRIE

Species and Stage	No. of Samples	Av. Date Collected	Chemical Composition in Per Cent						
			Crude Protein	Crude Fibre	Ether Extract	Nitrogen-free Extract	Total Ash	Calcium	Phosphorus
Salt sage (*Atriplex Nuttallii*)—									
Leaf	6	May 28	23·43	11·53	2·49	39·03	23·52	1·064	0·476
Flower	7	July 1	16·50	16·81	2·15	43·70	20·84	1·020	0·244
Medium seed	6	July 24	16·35	19·38	1·55	45·16	17·56	1·202	0·155
Cured	6	Oct. 7	10·35	24·46	2·20	50·81	12·18	1·458	0·103
Winter fat (*Eurotia lanata*)—									
Leaf	7	May 26	21·95	25·25	2·06	39·07	11·67	0·893	0·298
Flower	7	June 28	18·30	28·28	2·50	41·07	9·85	0·924	0·229
Medium seed	4	July 23	16·00	28·88	....	....	8·47	0·835	0·216
Cured	5	Oct. 15	11·23	27·65	1·07	52·08	7·97	1·494	0·093

It is evident that winter fat and salt sage contain more protein and minerals and less crude fibre than do the principal grasses in comparable growth stages. The calcium content is particularly high in comparison with that of the grass species. As a result, the ratio of calcium to phosphorus is higher than in the major grass species, particularly in the later growth stages.

The changes in chemical composition associated with growth development are much the same as in the grasses, although it is noteworthy that protein content does not decline so sharply in the broad-leaved species. The percentage of crude fibre in winter fat, while relatively high in the leaf stage, does not increase to such an extent in subsequent growth stages as in most grasses. The fibre content of salt sage is relatively low in all stages.

The broad-leaved forages of secondary importance were studied less fully than were winter fat and salt sage. The data are presented in Table 10.

TABLE 10.—CHEMICAL COMPOSITION OF FORBS AND SHRUBS OF SECONDARY IMPORTANCE

Species	Stage of Growth	Av. Date Collected	No. of Samples	Crude Protein	Crude Fibre	Ether Extract	Calcium	Phosphorus
Pasture sage								
(Artemisia frigida)	Leaf	May 25	3	18·16	27·58	5·79	0·810	0·340
	Cured	Oct. 21	2	7·58	33·22	3·07	0·620	0·110
Sagebrush								
(Artemisia cana)	Leaf	May 26	3	19·29	24·56	6·86	0·710	0·450
	Cured	Oct. 16	2	9·52	23·92	....	0·970	0·221
Ascending milk vetch *(Astragalus striatus)*	Flower	June 6	4	22·47	21·48	2·86	1·031	0·256
Spreading homalobus *(Homalobus tenellus)*	Flower	June 28	2	17·66	24·84	....	0·748	0·272
Narrow-leaved vetch[1] *(Cnemidophacos pectinatus)*	Flower	May 28	2	24·00	19·20	3·17	....	0·413
Two-grooved milk vetch[1] *(Diholcos bisculcatus)*	Flower	June 3	3	20·11	23·07	2·53	0·828	0·258
Russian thistle								
(Salsola Pestifer)	Leaf	June 23	6	21·30	11·67	1·87	2·494	0·301
" "	Flower	Aug. 14	3	18·00	23·57	1·85	1·800	0·200
" "	Seed	Sept. 3	3	10·72	24·70	....	1·503	0·213
Greasewood[2] *(Sarcobatus vermiculatus)*	Flower	Aug. 2	2	19,50	18·80	....	0·190	0·190
Western sea blite[2] *(Suaeda depressa)*	Flower	Aug. 2	1	16·30	14·00	2·85	0·260	0·100

[1] These species may be poisonous to livestock due to high selenium content when growing on soils rich in this mineral.
[2] Plants of saline soils.

The analyses indicate that these species, like those of Table 9, are generally superior to the grasses in percentage of protein and minerals and lower in crude fibre content. In addition, pasture sage and sagebrush have an exceptionally high fat content, even when in the cured stage. The legumes, as might be expected, are richer in protein than are most other plants. The leafage of Russian thistle is high in protein and very low in fibre. The calcium phosphorus ratio is high in most species of Table 10.

The data available indicate that the high ash content of the broad-leaved species of Tables 9 and 10 is not in most cases associated with a high percentage of silica. Only salt sage and Russian thistle equal the grasses of Table 7 in silica content.

Mixed Prairie Species

The principal forage plants of the Mixed Prairie include many species such as western wheatgrass, common speargrass, Junegrass and grama grass which are abundant in the Shortgrass Prairie. The chemical composition of these plants was discussed in a previous section. Other plants such as short-awned porcupine grass and northern wheatgrass are associated more particularly with mixed prairie vegetation, and it is species of this latter group which are treated in the present section. Since the study of mixed prairie forages was begun only recently, the data are not so complete as for the shortgrass prairie species. Analytical results for the principal plants are summarized in Table 11.

TABLE 11.—CHEMICAL COMPOSITION OF CERTAIN COMMON GRASSES OF MIXED PRAIRIE

Species and Stage of Development	No. of Samples	Av. Date of Collection	Chemical Composition in Per Cent						
			Crude Protein	Crude Fibre	Ether Extract	Nitrogen-free Extract	Total Ash	Calcium	Phosphorus
Northern wheatgrass (*Agropyron dasystachyum*)—									
Leaf	3	May 30	16·06	26·65	3·30	47·19	6·80	0·300	0·210
Late leaf	2	June 22	11·82	33·48	2·48	45·67	6·55	0·350	0·160
Cured	2	Oct. 18	4·10	36·66	3·00	46·59	9·49	0·530	0·070
Short-awned porcupine grass (*Stipa spartea* var. *curtiseta*)—									
Leaf	3	June 10	16·17	25·15	2·82	47·78	8·08	0·373	0·203
Flower	2	July 10	9·82	33·84	1·86	47·52	6·96	0·398	0·137
Green speargrass (*Stipa viridula*)—									
Leaf	2	May 26	25·50	21·00	....	....	10·66	0·450	0·245
Flower	2	June 22	13·56	32·34	....	....	9·16	0·420	0·160
Medium seed	2	July 23	8·50	35·52	1·78	46·59	7·61	0·400	0·150
Skyline bluegrass (*Poa Cusickii*)—									
Leaf	2	May 18	15·70	25·92	....	....	10·36	0·575	0·245

The available data indicate that the composition of the two most abundant species, northern wheatgrass and short-awned porcupine grass, is much the same as that of the principal shortgrass prairie species (*see* Tables 5 and 6). Green speargrass, on the other hand, tends to have a higher content of protein and calcium. The phosphorus content of most of the species of Table 11 is slightly lower than that of the main shortgrass prairie forms.

The changes in composition of mixed prairie forages with growth development appear to be much the same as in shortgrass prairie species, although the number of stages studied is not sufficient to provide for detailed comparison. The drop in protein and phosphorus with successive growth stages does not seem to be so rapid as for the shortgrass prairie forages.

Submontane Prairie Species

The native forages of the Submontane Prairie include not only many species characteristic of this zone but also a number which are abundant in Shortgrass and Mixed Prairie. The chemical composition of the principal species of this latter group, including Junegrass, northern wheatgrass and short-awned porcupine grass was discussed previously. Only species confined more or less to Submontane Prairie are considered in the present section. The data for grasses are presented in Table 12.

TABLE 12.—CHEMICAL COMPOSITION OF PRINCIPAL GRASSES OF SUBMONTANE PRAIRIE

Species	Growth Stage	Av. Date Collected	No. of Samples	Chemical Composition in Per Cent				
				Crude Protein	Crude Fibre	Total Ash	Cal-cium	Phos-phorus
Rough fescue								
(Festuca scabrella)	Leaf	June 16	3	12·00	30·25	10·14	0·300	0·185
" "	Late leaf	July 21	3	8·83	31·71	10·06	0·295	0·135
" "	Flower	June 26	2	8·58	33·15	11·42	0·185	0·180
" "	Medium seed	July 13	3	8·40	34·95	8·49	0·275	0·132
" "	Seed shed partly cured	Aug. 10	2	5·40	37·16	9·80	0·294	0·084
Idaho fescue								
(Festuca idahoensis)	Leaf	June 19	3	12·51	32·40	9·96	0·353	0·208
" "	Flower	July 10	3	8·45	33·36	8·04	0·318	0·145
Awned wheatgrass								
(Agropyron trachycaulum var. *unilaterale)*	Medium seed	Aug. 16	2	9·90	35·12	5·70	0·240	0·120
Wild oatgrass								
(Danthonia intermedia)	Leaf	July 13	3	10·80	32·05	9·14	0·269	0·175
" "	Medium seed	July 28	2	6·78	34·38	7·26	0·236	0·098
Hooker's oatgrass								
(Avena Hookeri)	Flower	July 12	2	9·76	34·90	8·76	0·440	0·290
Short-awned brome								
(Bromus breviaristatus)	Leaf	June 2	2	20·80	23·80	10·20	0·490	0·400
" "	Flower	July 3	2	9·87	33·75	9·38	0·470	0·260

Rough fescue, the principal forage species of Submontane Prairie is relatively low in protein and phosphorus and high in fibre when in the leaf stage. Its composition in subsequent growth stages is more comparable to that of the principal grasses of Shortgrass and Mixed Prairie. A somewhat similar condition occurs in Idaho fescue. Wild oatgrass is low in protein and phosphorus in all stages, and high in fibre when in leaf. Analysis of a single sample of Parry's oatgrass, not included in Table 12, indicates that the two oatgrasses probably are similar in chemical composition.

The available data for awned wheatgrass, Hooker's oatgrass and short-awned brome indicate that these species compare favourably in composition with the common grasses of other prairie zones. The latter two species are particularly rich in phosphorus.

Determination of ether extract made in a few cases, but not shown in Table 12, gave results comparable to those for common grasses of the Shortgrass and Mixed Prairie.

Changes in chemical composition with growth development follow apparently the same general course as for grasses in other zones. However, the decline in protein and phosphorus and increase in crude fibre are generally not so rapid as for the principal species of Shortgrass Prairie. This appears to be associated with the fact that curing of leafage occurs later in the growth development of submontane species than for those of drier areas.

In addition to grasses, several palatable broad-leaved herbs and shrubs occur commonly in Submontane Prairie. Data on the composition of some of the more important species are presented in Table 13.

TABLE 13.—CHEMICAL COMPOSITION OF BROAD-LEAVED FORAGE SPECIES, SUBMONTANE PRAIRIE

Species	Growth Stage	Av. Date Collected	No. of Samples	Chemical Composition in Per Cent				
				Crude Protein	Crude Fibre	Total Ash	Calcium	Phosphorus
American hedysarum								
(Hedysarum americanum)......	Leaf......	June 7	2	24·08	13·00	5·67	0·825	0·370
" "	Flower....	July 4	5	18·00	26·37	5·50	0·936	0·235
" "	Seed......	Aug. 3	3	16·40	27·92	6·02	1·172	0·185
Richardson's geranium *(Geranium Richardsonii)*........	Flower....	July 28	2	14·18	20·06	7·96	1·005	0·347
Silvery lupine *(Lupinus argenteus)*..........	Flower....	July 14	7	21·12	23·08	9·56	1·587	0·312
Northern bedstraw *(Galium boreale)*..............	Flower....	July 14	2	8·88	25·69	8·19	1·220	0·190
Shrubby cinquefoil *(Dasiphora fruticosa)*...........	Flower....	July 13	2	12·32	18·37	5·56	0·552	0·218

It is evident that these broad-leaved plants have a higher content of protein and minerals and less crude fibre than do most grasses in comparable stages. Most of the species of Table 13 are rich in calcium and some, such as wild geranium and lupine are high in phosphorus content.

Sandhill Species

Sandhill vegetation in the area studied is quite variable, comprising several associations and including species of grasses, forbs, shrubs and trees. However, the majority of the forbs and many of the shrubs and trees are not palatable to livestock. The forage species may be divided into the following main groups:—

(1) Species confined more or less to sandy areas.

(2) Plants which occur on both medium-textured and sandy soils.

The present section deals mainly with species of the first group. Data for the principal sandhill forages are presented in Table 14.

TABLE 14.—CHEMICAL COMPOSITION OF COMMON SANDHILL FORAGE SPECIES

Species and Stage	No. of Samples	Av. Date Collected	Chemical Composition in Per Cent						
			Crude Protein	Crude Fibre	Ether Extract	Nitrogen-free Extract	Total Ash	Calcium	Phosphorus
Sandgrass *(Calamovilfa longifolia)*									
Leaf....................	4	June 9	11·41	33·63	1·92	47·08	5·96	0·256	0·216
Flower................	2	July 30	6·66	34·64	2·00	51·18	5·52	0·247	0·180
Cured.................	2	Nov. 1	3·89	33·50	1·18	56·11	5·33	0·465	0·130
Sand dropseed *(Sporobolus cryptandrus)*									
Leaf..................	2	June 26	10·98	32·90	....	....	7·08	0·355	0·225
Cured................	2	Oct. 8	5·06	37·30	1·54	50·34	5·76	0·230	0·092
Indian rice *(Oryzopsis hymenoides)*									
Flower...............	2	June 30	10·78	32·44	....	....	6·44	0·490	0·180
Medium seed.........	4	July 16	7·30	34·12	2·11	50·46	6·01	0·440	0·145
Canada wild rye *(Elymus canadensis)*—									
Flower..............	2	July 29	9·16	34·91	2·54	49·38	4·44	0·230	0·220

Species and Stage	No. of Samples	Av. Date Collected	Chemical Composition in Per Cent						
			Crude Protein	Crude Fibre	Ether Extract	Nitro-gen-free Extract	Total Ash	Cal-cium	Phos-phorus
Little bluestem (*Andropogon scoparius*) Medium seed.........	2	Aug. 19	3·96	39·89	2·31	49·42	4·42	....	0·051
Chokecherry (*Prunus melanocarpa*)— Leaves and young shoots.............	2	June 27	14·48	11·56	....	....	6·92	1·890	0·200
Sandhill rose (*Rosa Macounii*) Leaves and young shoots.............	2	June 28	9·57	15·80	....	....	5·10	1·350	0·170
Sandbar willow (*Salix interior*) Leaves and young shoots.............	2	June 27	11·19	19·36	....	....	7·08	1·990	0·210
Lance-leaved psoralea (*Psoralidium lanceolatum*) Leaf..................	2	June 27	17·57	22·91	....	....	6·42	1·200	0·190

In their earlier growth stages, two of the principal species, sandgrass and sand dropseed have lower contents of protein and phosphorus and higher amounts of crude fibre than the main grasses of normal prairie (*see* Tables 5, 6, 11). These differences are much less marked in the cured stage. Little bluestem is decidedly low in protein and phosphorus and high in crude fibre in the seed stage. Two other species, Indian rice and Canada wild rye have much the same composition as the grasses of finer soils. All the sandhill grasses appear relatively low in percentage of total ash. Analysis of silica content was made for a few samples. The data, not shown in Table 14, indicate no appreciable difference between sandhill grasses and those of normal prairie in silica content.

Leaves and young shoots of chokecherry and willow collected at the end of June were higher in protein and minerals and lower in fibre than most of the grasses at this date, when the latter were in sheath or flower. Similar material of Rosa was relatively low in protein and phosphorus compared to the other shrubby species. Lance-leaved psoralea was relatively low in protein and phosphorus for a legume.

The data in Table 14 indicate that changes in chemical composition associated with growth development are probably much the same in sandhill plants as in those of normal prairie. There may be exceptions to this, as in the case of sandgrass, where the content of crude fibre apparently remains relatively constant from the leaf to the cured stage.

As noted earlier in this section, several important species occur both on sandy and medium textured soils. The most abundant grass of this type in sandhill areas is common speargrass, while Junegrass, wheatgrasses and grama grass are common. Comparison of these species grown on loam prairie soils and in sand indicates that the principal difference is in phosphorus content which is lower in the latter case. The data are presented in a subsequent section under the title "Effects of Soil Type on Chemical Composition".

On the whole it appears that many forage plants of the sandhills tend to have a lower content of protein, total ash and particularly phosphorus than have the principal species of normal prairie. More study of the composition of plants growing in sandy areas is needed to determine the extent of this difference and its significance in relation to grazing use. Possible deficiencies in the herbaceous forage may be offset to a large degree by the abundance of browse feed.

Forest Species

The information regarding the chemical composition of the native forages of forest areas is much less complete than that available for grassland ranges. Most of the data are from the analysis of samples collected in areas of predominantly coniferous forest in the Cypress Hills and Rocky Mountain Foothills. Few samples have been obtained from deciduous forest ranges, and no study has been made of possible differences in composition of species growing in the two forest types. A summary of the available data is presented in Table 15.

TABLE 15.—CHEMICAL COMPOSITION OF COMMON FORAGE SPECIES OF FOREST ZONES

Species	Growth Stage	Av. Date Collected	No. of Samples	Chemical Composition in Per Cent				
				Crude Protein	Crude Fibre	Total Ash	Calcium	Phosphorus
Pinegrass								
(Calamagrostis rubescens)	Leaf	July 2	5	12·22	31·80	12·13	0·333	0·254
" "	Flower	Aug. 5	3	8·40	36·80	8·14	0·270	0·240
" "	Medium seed	Aug. 15	2	5·54	35·67	14·53	0·410	0·160
Purple oatgrass								
(Schizachne purpurascens)	Flower	June 22	2	9·79	34·18	10·69	0·200	0·210
Fringed brome								
(Brome ciliatus)	Flower	July 3	1	9·92	34·97	10·69	0·400	0·300
Canada brome								
(Bromus purgans)	Flower	July 4	2	11·30	36·00	8·97	0·330	0·267
Smooth aster								
(Aster laevis)	Leaf	June 22	1	18·30	12·78	11·63	0·110	0·420
Veiny peavine								
(Lathyrus venosus)	Leaf	June 18	1	29·50	27·94	7·54	0·998	0·410
American vetch								
(Vicia americana)	Flower	June 29	2	19·96	29·53	8·50	1·428	0·211
Willows								
(Salix spp.)	Leaf	June 14	4	17·93	15·84	7·39	1·170	0·415
Aspen poplar								
(Populus tremuloides)	Leaf	July 3	2	18·23	17·36	6·84	1·090	0·370
Saskatoon bush								
(Amelanchier alnifolia)	Leaf	July 14	2	13·90	21·29	7·28	0·990	0·350

Pinegrass, the principal forage species of the coniferous forest areas, is relatively low in protein and high in crude fibre, particularly when in the leaf stage. The composition of purple oatgrass and the two bromes resembles more nearly that of the common prairie grasses, and all three are rich in phosphorus. Data on percentage of nitrogen-free and ether extract were not obtained for most of the forest grasses.

The data for broad-leaved forage species indicate that they are well supplied with nutrient elements, being generally higher in percentage of protein and minerals and lower in fibre content than the grasses. The two legumes, American vetch and veiny peavine are particularly high in protein content, while the latter species together with smooth aster and willow is outstanding in percentage of phosphorus. Data for fat content, obtained for a few of the broad-leaved plants but not included in Table 15, indicate that these species are as well supplied with this element as are most prairie grasses. The percentage of nitrogen-free extract is higher than in grasses of either prairie or forest.

The data in Table 15 are not sufficient to throw much light on the changes in chemical composition undergone by these forest species during seasonal growth development. It would appear that the changes are somewhat similar to those taking place in Submontane Prairie species and less marked than in plants of the drier prairie zones.

Meadow Species

Scattered throughout the zones discussed previously are low-lying areas such as meadows, sloughs and swamps where soil moisture is abundant. The vegetation of these areas is affected primarily by the local soil moisture condition and is much less influenced by climatic factors than is the plant cover of the uplands. For this reason, certain species such as slough grass, awned sedge and Baltic rush occur commonly in low areas throughout southern Saskatchewan and Alberta. Hence, the lowland species of this whole region are treated here as a separate group. These meadow plants are of great importance in relation to livestock production, since they constitute the bulk of the native hay harvested in the area, as well as supplying considerable grazing. The data for meadow grasses are presented in Table 16.

TABLE 16.—CHEMICAL COMPOSITION OF PRINCIPAL MEADOW GRASSES IN SOUTHERN SASKATCHEWAN AND ALBERTA

Species	Growth Stage	Av. Date Collected	No. of Samples	Chemical Composition in Per Cent				
				Crude Protein	Crude Fibre	Total Ash	Calcium	Phosphorus
Slough grass								
(Beckmannia Syzigachne).......	Flower....	June 27	2	9·25	32·70	7·46	0·240	0·180
" "	Medium seed....	Aug. 9	2	5·00	35·11	12·00	0·300	0·150
Tufted hairgrass								
(Deschampsia caespitosa).......	Leaf......	May 22	2	17·58	31·62	8·48	0·470	0·228
" "	Flower....	June 29	2	8·40	35·29	9·28	0·260	0·205
" "	Medium seed....	July 24	3	6·65	37·36	8·81	0·310	0·200
Tall mannagrass								
(Glyceria grandis).............	Leaf......	June 16	2	21·85	22·72	12·30	0·435	0·370
" "	Flower....	July 13	3	8·50	32·01	8·45	0·370	0·253
" "	Seed shed	Aug. 3	3	6·40	29·67	10·77	0·404	0·162
Marsh reedgrass								
(Calamagrostis canadensis)......	Leaf......	June 16	2	12·35	30·76	7·52	0·325	0·148
" "	Flower....	July 17	5	8·26	36·68	6·91	0·345	0·141
" "	Seed......	Aug. 12	2	6·70	34·20	6·93	0·354	0·104
Northern reedgrass								
(Calamagrostis inexpansa)......	Leaf......	June 2	1	18·80	27·30	10·70	0·380	0·200
" "	Flower....	Aug. 10	2	7·10	34·43	11·02	0·480	0·155
Reed canary grass								
(Phalaris arundinacea)..........	Flower....	July 26	1	9·77	38·52	8·91	0·300	0·300
Spangle top								
(Fluminea festucacea)..........	Leaf......	June 22	1	12·90	27·10	8·28	0·330	0·220
" "	Flower....	July 18	1	8·00	32·46	7·45	0·210	0·120

It is evident that most of these plants are fairly well supplied with nutrient elements. The protein content is a little lower and the percentage of fibre higher than in the main shortgrass species (Table 6), but the phosphorus content averages about the same. Slough grass, tufted hairgrass, tall mannagrass and reed canary grass are somewhat superior to the reed grasses and spangle top in percentage of the more desirable constituents.

The changes in composition occurring with seasonal growth development appear to be similar in general to those found in upland species. However, in tall mannagrass and marsh reedgrass the fibre content apparently decreases from the flowering to the seed or seed shed stages. The reason for this deviation from the normal trend is not evident.

Non-grasses, chiefly sedges and related forms, constitute a large proportion of the lowland vegetation in most areas. Analytical data for this group are presented in Table 17.

TABLE 17.—CHEMICAL COMPOSITION OF SEDGES AND RUSHES IN SOUTHERN SASKATCHEWAN AND ALBERTA

Species	Growth Stage	Av. Date Collected	No. of Samples	Chemical Composition in Per Cent				
				Crude Protein	Crude Fibre	Total Ash	Calcium	Phosphorus
Water sedge								
(Carex aquatalis)...............	Leaf......	June 28	3	18·82	24·50	7·64	0·427	0·340
" "	Flower....	July 11	3	12·20	27·03	8·92	0·320	0·207
" "	Medium seed....	July 31	3	10·60	28·52	8·30	0·570	0·147
Awned sedge								
(Carex atherodes)...............	Leaf......	June 12	5	17·27	26·98	7·77	0·448	0·250
" "	Flower....	July 5	2	12·16	27·33	7·52	0·460	0·160
" "	Medium seed....	July 26	4	10·18	28·60	8·03	0·599	0·163
Spike rush								
(Eleocharis palustris)..........	Leaf......	May 24	2	22·10	20·40	11·46	0·545	0·405
" "	Flower....	June 7	5	16·30	23·21	6·90	0·405	0·230
" "	Medium seed....	June 21	2	11·18	27·52	9·98	1·300	0·220
Baltic rush								
(Juncus ater)..................	Leaf......	May 26	3	15·60	27·00	8·23	0·377	0·213
" "	Flower....	June 23	2	12·16	28·68	5·62	0·326	0·149
" "	Medium seed....	Aug. 4	4	9·18	29·44	5·14	0·363	0·120
Three-square bulrush								
(Scirpus americanus)...........	Medium seed....	Aug. 3	2	9·07	29·96	7·90	0·416	0·149

It is evident that the species of Table 17 compare favourably with the meadow grasses, being generally higher in protein and phosphorus and lower in crude fibre than the latter. In the flowering stage particularly, the sedges and

FIGURE 5.—Good growth in a native meadow. The stand consists mainly of tall mannagrass and coarse sedges. Such vegetation produces hay of fair quality if cut early.

rushes appear superior not only to the lowland grasses but also to most upland species (*see* Tables 6, 11). Data for ether extract, obtained for a few samples but not shown in Table 17 indicate that the sedges are low in this constituent. The percentage of fat varies from one to two per cent in the leaf stage and declines with growth development.

Data for silica content, not shown in Tables 16 and 17, indicate that most of the meadow species contain about the same percentage of this element as do the principal upland grasses. Tall mannagrass and Baltic rush are a little higher in silica, averaging nearly five per cent in the flowering stage, although the amount varies considerably in different samples. Gordon and Sampson (19) found spike rush to be very high in silica, but such was not the case in the present study.

The data in Table 16 do not give a full picture of changes in composition with growth development, particularly since no analyses of cured forage were made. The seed stage in most of the meadow plants occurs in late July or early August, while the foliage is still green. Analyses of native hay samples, cut at different growth stages and dates, indicate that the drop in desirable constituents is very rapid in most meadow species once curing begins. Data on this point are presented in Table 18.

TABLE 18.—CHEMICAL COMPOSITION OF NATIVE MEADOW HAY CUT IN VARIOUS GROWTH STAGES

Growth Stage	No. of Samples	Date Cut	Chemical Composition in Per Cent						
			Crude Protein	Crude Fibre	Ether Extract	Nitro-gen-free Extract	Total Ash	Cal-cium	Phos-phorus
Leaf	2	June 22	15·61	24·32	1·54	51.53	7·00	0·435	0·225
Late seed	2	Mid-Aug	9·50	29·40	0·95	52·20	8·06	0·390	0·120
Seed shed, 20% cured	2	Early Sept.	8·70	32·54	0·83	50·81	6·84	0·340	0·110
50% Cured	2	Oct. 10	6·14	31·94	0·95	54·31	6·66	0·520	0·085

This hay consisted mainly of awned sedge, together with lesser amounts of spangle top, reed grasses, etc. All samples were from the same site. It will be noted that the percentage of ether extract and phosphorus declined sharply once the seed stage was reached, and reached a very low point by the time the forage was half cured. Protein declined also to a considerable extent. These data are important in connection with the quality of native meadow hay, which is often poor, due to being cut at a late stage of growth.

Cultivated Species

There are a few cultivated grasses which warrant mention because of their use in reseeding abandoned fields and depleted native pastures. The most important member of this group at present is crested wheatgrass, which is being used extensively for reseeding purposes. This species is well adapted to the conditions existing in the Shortgrass and Mixed Prairie areas, and appears to have become established as a permanent constituent of grazing lands in these regions. Common bromegrass is suited to the Submontane and Parkland zone and to favoured areas in the Mixed Prairie area. Slender wheatgrass ("western rye") is valuable chiefly for its tolerance of alkaline conditions. Neither of the latter two species has been used for reseeding on nearly so large a scale as crested wheatgrass.

Samples of all three grasses were obtained from dryland plots at the Manyberries Station while several collections of crested wheatgrass were made in reseeded fields in the vicinity of Swift Current. The data are presented in Table 19.

TABLE 19.—CHEMICAL COMPOSITION OF IMPORTANT CULTIVATED GRASSES IN SOUTHERN SASKATCHEWAN AND ALBERTA

Species and Stage	No. of Samples	Av. Date of Collection	Chemical Composition in Per Cent						
			Crude Protein	Crude Fibre	Ether Extract	Nitrogen-free Extract	Total Ash	Calcium	Phosphorus
Crested wheatgrass (*Agropyron cristatum*)—									
Leaf	8	May 10	22·70	19·94	2·69	45·83	8·85	0·417	0·274
Emerging from sheath	3	June 8	13·85	29·20	1·60	48·00	7·45	0·285	0·240
Flower	8	June 29	11·66	33·07	1·81	46·34	7·12	0·318	0·187
Medium seed	8	July 30	8·54	32·53	1·91	51·10	5·92	0·327	0·144
Cured	5	Oct. 21	4·45	34·72	1·86	52·12	6·85	0·300	0·051
Common bromegrass (*Bromus inermis*)—									
Leaf	3	May 12	26·90	18·13	....	....	....	0·450	0·220
Flower	3	July 15	13·10	30·56	....	....	7·78	0·335	0·170
Cured	1	Sept. 29	7·10	34·97	....	....	....	0·260	0·060
Slender wheatgrass (*Agropyron trachycaulum*)—									
Leaf	2	May 12	25·00	20·10	....	....	....	0·355	0·250
Flower	3	July 10	11·45	33·80	....	....	7·84	0·330	0·170

All three species are well supplied with nutrient elements and tend to be somewhat superior to most native grasses in this regard. Crested wheatgrass is higher in protein and phosphorus content than the average for shortgrass dominants (Table 6) in all but the cured stage. The percentage of crude fibre, nitrogen-free extract and total ash is much the same as in the grasses of Table 6, while the content of ether extract is slightly lower.

FIGURE 6.—Abandoned field in the Shortgrass Prairie area, reseeded to crested wheatgrass. This grass controls weed growth and yields about three times as much forage as does the native sod in this zone.

Common brome and slender wheatgrass are both slightly higher in protein and lower in phosphorus than crested wheatgrass. The phosphorus content of the bromegrass samples appears abnormally low. Sotola (41) in Washington, found the phosphorus content to be 0·320 per cent in the leaf stage and 0·200 per cent in flower for this species, while Morrison (32) gives a figure of 0·320 per cent for phosphorus in brome hay. Brome did not thrive on the dryland plots at Manyberries, and this condition may have affected the phosphorus content. The fact that the same species on irrigated plots at this Station had a phosphorus content of 0·230 per cent in the flowering stage lends support to the view that lack of moisture was responsible for the low content of this element in the dryland material.

DISCUSSION OF RESULTS

Analytical results have been presented for approximately 75 species including the principal forages of five major vegetation types as well as native meadow plants and certain cultivated grasses. Points arising from these data will be discussed under the following headings:—

1. Variability of the data.
2. Correlation between chemical constituents.
3. Differences in composition between species and stages of development.
4. Changes in chemical composition with growth development.
5. The leaf-stem ratio in relation to chemical composition.

Variability of the Data

The study reported in this publication was conducted to determine the chemical composition of a large number of native forage species in a variety of range types. For the main forage species of the Shortgrass Prairie zone, sampling was done in such a manner as to permit statistical treatment of the results. Samples of these plants were collected annually from the same sites in each of several growth stages for a number of years. Thus variability due to differences in site and soil type was controlled to a great extent, although the effects of variations in climate from year to year were not eliminated.

The data for variability of the results for certain species are presented in Table 20.

TABLE 20.—VARIABILITY OF DATA FOR CHEMICAL COMPOSITION OF PRINCIPAL NATIVE FORAGE SPECIES OF THE SHORTGRASS PRAIRIE ZONE

Species and Stage	No. of Samples	Variability in Per Cent[1]				
		Crude Protein	Crude Fibre	Total Ash	Calcium	Phosphorus
Common speargrass (*Stipa comata*)—						
Leaf	8	3·0	3·7	4·6	6·4	3·0
Flower	8	5·0	2·7	8·4	8·1	7·0
Seed	6	8·3	2·7	5·7	9·7	7·3
Cured	7	11·0	5·0	8·8	9·3	9·0
Av. for 4 species[2]—						
Leaf	....	4·9	5·5	8·1	9·9	5·2
Flower	....	5·5	2·6	7·6	8·3	5·7
Medium seed	....	9·7	3·8	6·0	9·9	8·4
Cured	....	12·0	3·4	8·6	8·8	11·2

[1] Standard Error ($s_{\bar{x}}$) expressed in per cent of the mean for each variable.

[2] Western wheatgrass, grama grass, Junegrass and common speargrass.

The data indicate that where six to eight samples were obtained, the sampling error was below 10 per cent of the mean for most constituents. Such a degree of variability cannot be considered unduly high in material of this type.

The various chemical constituents differed considerably in variability. Crude fibre content was generally least, and the percentage of calcium most variable. There were marked differences among growth stages in this regard. For example, protein and phosphorus were more variable in the seed and cured stages than in the leaf or flowering stages.

There were no marked differences in variability among the species of Table 20. Results for other important forage species of the Shortgrass Prairie such as crested wheatgrass, salt sage and winter fat were found to vary to much the same extent. In all cases crude fibre was the least variable constituent, while the variability of most components was least in the leaf and flowering stages.

Few studies have been made of the variability of data from chemical analyses of range forages. Stoddart (43) in a recent investigation with a single species (roundleaf snowberry), in Utah found time of collection, soil type and nature of site to be the principal factors affecting chemical composition. The variability of crude fibre proved to be higher than that of protein, phosphorus or calcium. These latter results are not in accord with the findings of the present study, but the discrepancy may be due to the difference in material used. Data presented by Kik (26) for samples of little bluestem in Arkansas show less variability for crude fibre than for any other constituent except total ash.

Results of the present study indicate that the leaf and flowering stages generally are most suitable for comparative studies of the chemical composition of prairie forages since the variability of most constituents is at a minimum. The flowering stage has the additional advantage of being one which lasts for a relatively short and definite period in most species.

Correlation Among Chemical Constituents

In order to determine the degree of association among the various constituents, correlation coefficients were calculated in certain cases. The most suitable results for this purpose were those for the forages of the Shortgrass zone along with a few major species in other zones.

Correlation data for the five major grasses of the Shortgrass Prairie in several growth stages are presented in Table 21.

TABLE 21.—CORRELATION OF CHEMICAL CONSTITUENTS IN FIVE MAIN GRASSES OF SHORTGRASS PRAIRIE

Constituents Compared	No. of Samples	Value of r	Value of r at 1% Point	Significance
Crude protein and phosphorus	32	+ 0·93	0·449	High
" " " crude fibre	32	− 0·86	0·449	"
" " " nitrogen-free extract	25	− 0·75	0·505	"
Crude fibre and phosphorus	32	− 0·77	0·449	"
Nitrogen-free extract and phosphorus	25	− 0·67	0·505	"

Data include all stages from leaf to "after winter exposure".

The data indicate a strong positive association between protein and phosphorus, with each of these constituents correlated negatively with fibre and nitrogen-free extract. No significant relationship was found among any other of the constituents. Calculations made for crested wheatgrass gave correlations similar to those shown in Table 21.

The above relationships are in accord with the seasonal trend of constituents in these grasses. Protein and phosphorus decrease greatly with growth development, while crude fibre and nitrogen-free extract increase.

Correlations for 30 grasses and sedges of major forage importance in the prairie zones (sandhills included) are presented in Table 22. The data are for two or more of the leaf, flowering, seed and cured stages for each species.

TABLE 22.—CORRELATION OF CHEMICAL CONSTITUENTS IN MAIN GRASSES OF ALL PRAIRIE ZONES

Constituents Compared	No. of Samples	Value of r	Significance
Crude protein and phosphorus	77	+0·79	High
" " " crude fibre	77	−0·73	"
" fibre and phosphorus	77	−0·51	"
Phosphorus and total ash	77	+0·11	None
Calcium and phosphorus	77	+0·18	"

Value of r at the 1 per cent point =0·314.

It will be noted that the positive correlation between protein and phosphorus and the negative association between each of these constituents and crude fibre is as strong as for the species of Table 21. There is no correlation between phosphorus and either calcium or total ash.

Possible associations for other constituents such as nitrogen-free extract were not calculated due to lack of the necessary data for some species. For the same reason no attempt was made to determine correlations among constituents of the broad-leaved forages.

It would appear that, considering all growth stages, there is a high degree of association among protein, crude fibre and phosphorus in the main grasses and sedges of the prairie zones. Nitrogen-free extract is correlated with each of the above components in the major short-grass prairie species, and the same relationship may hold for the grasses of all zones. There is no indication of correlation between any of the above components and calcium or total ash.

A positive correlation between protein and phosphorus in pasture herbage has been reported by Daniel (13) in Oklahoma, Greaves (20) in Utah and numerous workers in more humid pasture regions.

Greaves found other correlations including a positive one between calcium and total ash and negative associations between protein and fibre, phosphorus and fibre, phosphorus and calcium, phosphorus and total ash and between fibre and nitrogen-free extract. This study was made with cured samples of both grasses and broad-leaved forage species. Greaves concluded that phosphorus content was a good indication of the nutritive value of the plants used in this experiment, since protein and crude fat varied directly with phosphorus content while crude fibre varied inversely.

Comparison of the data obtained in the present study with those of the workers mentioned above indicates that a positive relationship between protein and phosphorus is of general occurrence in pasture forages. A negative correlation between each of the above constituents and crude fibre may be common also. Certain other relationships, such as those of phosphorus with calcium and total ash, and of nitrogen-free extract with protein and phosphorus, appear to vary with the material studied.

Differences Among Species and Growth Stages

The data presented previously indicate the existence of differences in the composition of various forages and particularly in different growth stages of the same species. A statistical analysis was made of some of the data in order to determine the extent of these differences. Results for Shortgrass Prairie species were used to a large extent, since the data for other zones were less complete.

Analysis of variance applied to data for the five main grasses of the Shortgrass area showed no significant difference among species in protein and phosphorus, the F value falling well below significance in each case. With crude fibre the F value was significant and the minimum significant difference was 1·95 per cent. The crude fibre content of grama grass was thus significantly lower than that of the other four species.

Data for differences between growth stages are presented in Table 23.

TABLE 23.—DIFFERENCES IN AVERAGE CHEMICAL COMPOSITION OF THE FIVE MAIN GRASSES OF THE SHORTGRASS PRAIRIE IN VARIOUS GROWTH STAGES

Growth Stage	Chemical Composition in Per Cent		
	Crude Protein	Crude Fibre	Phosphorus
Leaf	18·14	25·0	0·255
Sheath	13·10	28·6	0·210
Flower	9·74	32·8	0·183
Medium seed	7·18	33·5	0·130
Cured	5·02	34·5	0·085
After winter	3·96	35·1	0·062
Minimum significant difference between stages	1·75	2·10	0·035

It will be noted that differences in protein content between any two stages are significant in all but the cured and "after winter" samples. The crude fibre content differs significantly between leaf and sheath and between these and all later stages. The phosphorus content differs significantly between most stages of development.

A similar statistical analysis was made for 25 major grass and sedge species of the prairie region, including Shortgrass, Mixed and Submontane Prairie as well as sandhill areas and native meadows. Comparative data for this number of species were available for the leaf, flower and seed stages only. While analyses in other stages, especially the cured forage would have strengthened the comparison, the three stages used are considered to be representative. Analysis of variance revealed significant differences between both species and stages.

The data for differences in composition in various growth stages are presented in Table 24.

TABLE 24.—DIFFERENCES IN AVERAGE CHEMICAL COMPOSITION OF TWENTY-FIVE IMPORTANT FORAGE SPECIES IN SOUTHERN ALBERTA AND SASKATCHEWAN IN VARIOUS GROWTH STAGES

Growth Stage	Chemical Composition in Per Cent		
	Crude Protein	Crude Fibre	Phosphorus
Leaf	18·1	24·3	0·269
Flower	12·1	29·5	0·200
Medium seed	9·5	30·4	0·165
Minimum significant difference[1]	3·26	4·1	0·064

[1] The variability of this material, representing species of very different nature growing under widely differing climatic and soil conditions, was much greater than for that of Table 23.

The percentage of all three constituents in the leaf stage is significantly higher than in material in the flower and seed stages, but there are no significant differences between the latter two stages.

Data for differences among species may be summarized as follows:—

Protein.—There are few significant differences among the principal grasses of the prairie zones. Certain species, including green speargrass and crested wheatgrass (early growth stages only) are above average in protein, being significantly superior to grama grass, sandgrass, rough fescue and wild oatgrass in this regard. The broad-leaved forage species included in the study are all significantly higher in protein than the principal grasses.

Fibre.—Most of the principal grasses of the prairie zones do not differ significantly among themselves. A few species, including sandgrass, wild oatgrass and marsh reedgrass are significantly higher in fibre than are the principal grasses. The majority of the broad-leaved forages are significantly lower in fibre than any of the grasses studied.

Phosphorus.—Although the main prairie grasses vary considerably in content of this element, there are few significant differences among species. A few plants, including saltgrass, wild oatgrass and marsh reedgrass are significantly lower in phosphorus than the principal grasses. Most of the broad-leaved forage species are significantly superior to the grasses in phosphorus content.

The principal grasses of the prairie zones appear to be reasonably similar in content of protein, fibre, phosphorus and other constituents. The correlation between protein, fibre and phosphorus is illustrated by the fact that species low in protein usually are high in fibre and poor in phosphorus content. Most of the broad-leaved forage species are significantly higher in protein and phosphorus and lower in fibre than the grasses.

Changes in Chemical Composition with Growth Development

It has been shown in the preceding section that statistically significant changes in chemical composition occur in the shortgrass prairie grasses during growth development. Similar trends are evident in the data for other grasses, sedges, forbs and shrubs from all the major zones.

These changes may be summarized as follows:—

(1) Crude protein is at a maximum in the early leaf stage and declines greatly as growth development proceeds. The minimum content is reached in the cured forage which has been exposed throughout the winter.

(2) The percentage of crude fibre varies in an opposite manner to protein, being lowest in the leaf stage and highest after winter exposure.

(3) The content of ether extract declines irregularly from a maximum in the early growth stages to a minimum in the cured forage after winter exposure.

(4) The percentage of nitrogen-free extract increases gradually from the leaf to the cured stage but decreases slightly with winter exposure.

(5) Total ash content in grasses follows a curvilinear trend, with maxima in the leaf and cured stages and the minimum near the flowering stage. The percentage of silica-free ash actually declines throughout growth development. The trend for total ash is due to fluctuations in the silica content. In many broad-leaved forages the ash content is higher and the percentage of silica lower than in the grasses, so that the downward seasonal trend shows even in the figures for total ash.

(6) The calcium content of several grasses of the Shortgrass zone exhibits a curvilinear trend similar to that for total ash. In many other grasses and broad-leaved species no definite seasonal trend is apparent.

(7) The percentage of phosphorus declines throughout growth development in a manner similar to protein.

The seasonal trends in the various constituents are illustrated in Figures 7, 8, 9 and 10.

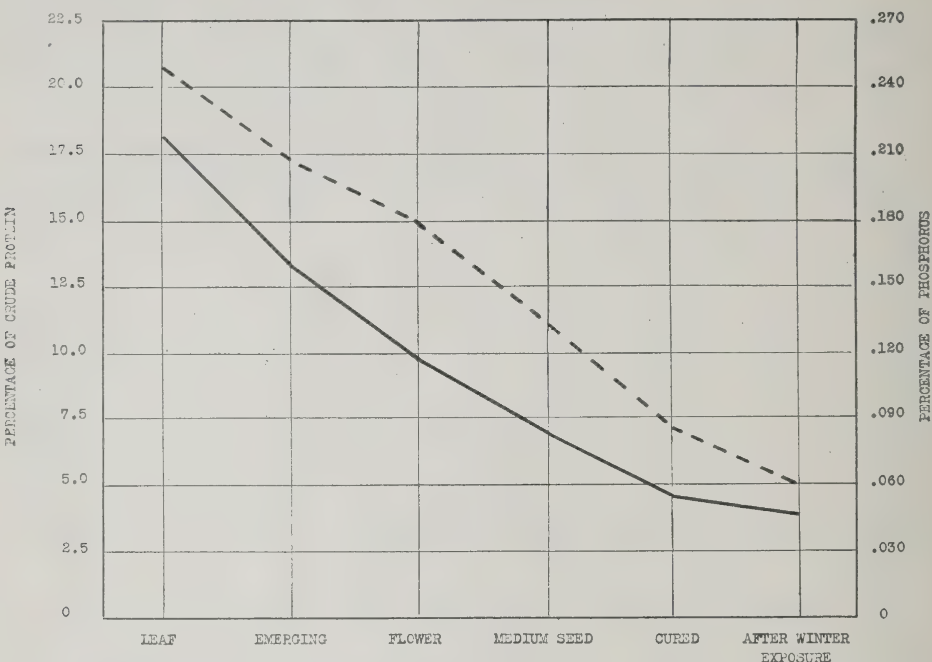

FIGURE 7.—Seasonal trend in percentage of crude protein (solid line) and phosphorus (broken line) in five principal grasses of the Shortgrass Prairie.

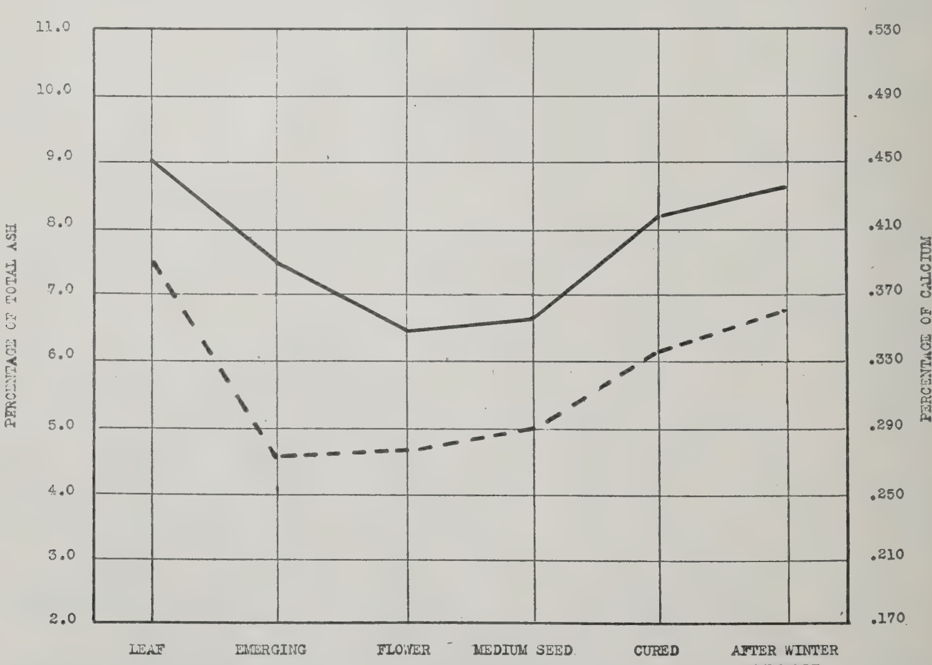

FIGURE 8.—Seasonal trend in percentage of total ash (solid line) and calcium (broken line) in five principal grasses of the Shortgrass Prairie.

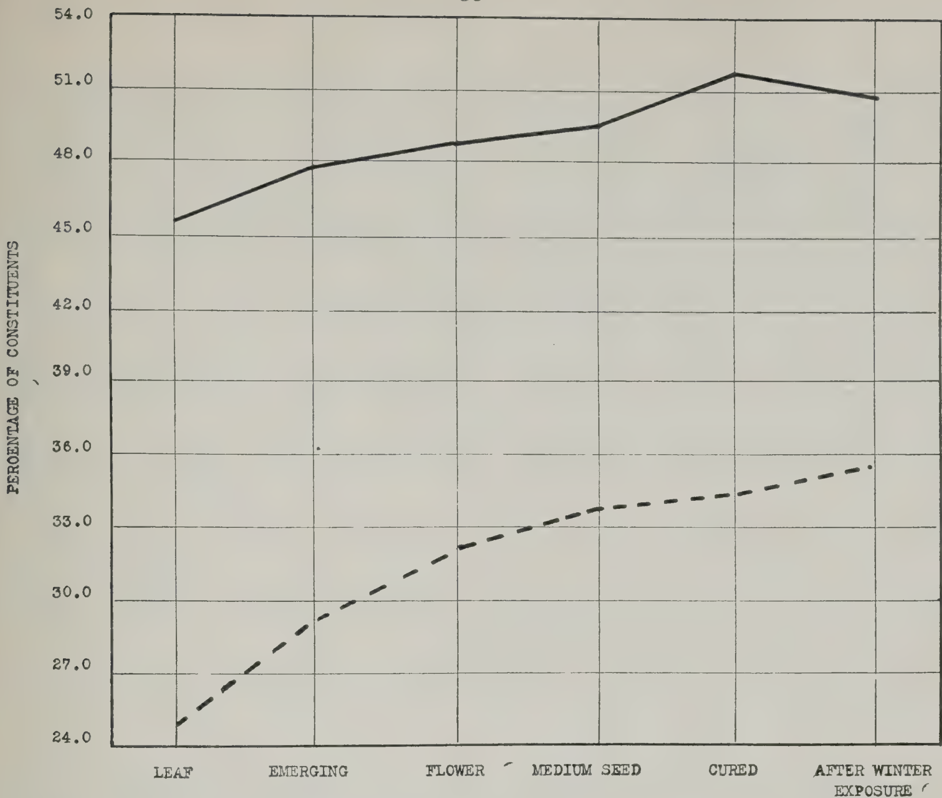

FIGURE 9.—Seasonal trend in percentage of nitrogen-free extract (solid line) and crude fibre (broken line) in five principal grasses of the Shortgrass Prairie.

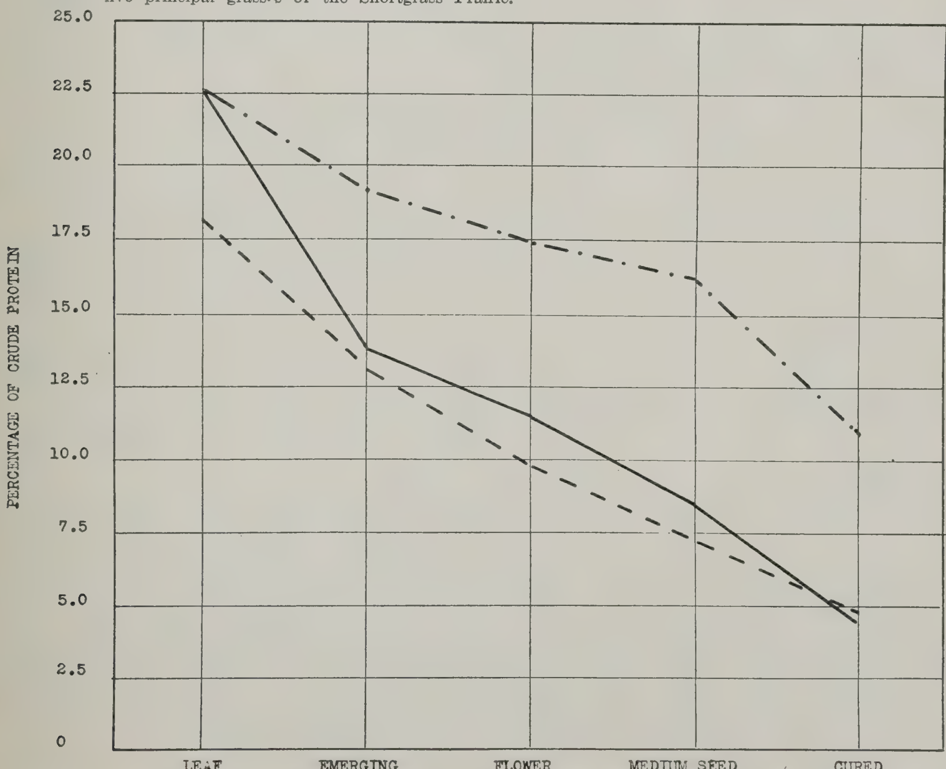

FIGURE 10.—Seasonal trend in crude protein content of crested wheatgrass (solid line), in five principal grasses of Shortgrass Prairie (broken line) and average for winter fat and salt sage (broken and dotted line).

The data for seasonal changes in protein, phosphorus, crude fibre and nitrogen-free extract are in agreement with the findings of other investigators. It is accepted generally that the percentage of the first two constituents decreases while that of the latter two increases in growth development.

The irregular but generally downward trend for ether extract found in these studies is in accord with the findings of other workers. The extreme variability in data for this constituent is apparent in the results of most investigators, and has been shown statistically by Stoddart (43).

Comparison of the data for ash is complicated by the fact that few workers appear to have made determinations of silica-free ash. A high content of silica, present in most grasses and grass-like species, as well as in many forbs, may mask seasonal trends in other ash elements as has been shown in the present study. Gordon and Sampson (19) working with California range species, found a downward seasonal trend in silica-free ash. Lack of any definite trend in total ash has been reported by several workers (25, 42). McCall (30) found a seasonal increase in total ash for bluebunch fescue, but notes that the silica content was high.

Several investigators (19, 42) have commented on the discrepancies in the results reported for trends of calcium in pasture species. Seasonal increases, decreases and lack of any definite trend have all been reported. The curvilinear trend found in some grasses (Tables 5, 6) in the present study appears to be somewhat different from anything reported to date. However, the data indicate that this trend is not followed closely by all grasses, even in the Shortgrass Prairie group, and there is no evidence that it is of general occurrence in other zones and plant groups.

The Leaf-stem Ratio in Relation to Chemical Composition

The relative effects of leaf and stem production in grasses were studied by means of (1) separate analyses of foliage and culms from samples of a few major species of the Shortgrass zone and (2) analyses of plants which remained in the leaf stage throughout the season.

The data on leaf and culm samples are presented in Table 25.

TABLE 25. CHEMICAL COMPOSITION OF LEAFAGE AND CULMS IN SOME PRAIRIE GRASSES

Species and Material	No. of Samples	Av. Date Collected	Chemical Composition in Per Cent				
			Crude Protein	Crude Fibre	Total Ash	Calcium	Phosphorus
Junegrass *(Koeleria cristata)*							
Cured, leaf only	3	Oct. 7	7·40	30·46	11·51	0·540	0·100
Cured, culms only	3	Oct. 7	3·92	33·94	6·08	0·237	0·057
Common speargrass *(Stipa comata)*							
Cured, leaf only	3	Sept. 27	6·94	28·75	7·19	0·525	0·135
Cured, culms only	3	Sept. 27	3·78	33·94	4·76	0·201	0·057
Grama grass *(Bouteloua gracilis)*							
Cured, leaf only	3	Oct. 4	7·75	25·57	9·84	0·473	0·112
Cured, culms only	3	Oct. 4	5·30	32·03	6·71	0·261	0·108

In each species there are marked differences in chemical composition between the leaf and culm material. The leafage generally is richer in protein, total ash, calcium and phosphorus, and lower in percentage of crude fibre. In grama grass the culms are unusually high in phosphorus content, nearly equalling the leaves in this regard. Separate analyses of leaf and culm were not made in early growth stage, but it seems likely that differences in chemical composition between foliage and stems occur throughout growth development.

The data for the composition of grass foliage at different times during the season along with comparative data for material in the flowering stage are presented in Table 26.

TABLE 26.—THE CHEMICAL COMPOSITION OF CERTAIN PRAIRIE GRASSES IN LEAF AT DIFFERENT TIMES DURING THE YEAR AND IN THE FLOWERING STAGE

Species and Stage	No. of Samples	Av. Date Collected	Chemical Composition in Per Cent				
			Crude Protein	Crude Fibre	Total Ash	Cal-cium	Phos-phorus
Western wheatgrass *(Agropyron Smithii)*							
Medium leaf	8	May 27	17·80	27·84	8·36	0·372	0·219
Late leaf	4	July 4	12·95	32·50	8·17	0·402	0·191
Flower	9	July 3	10·00	33·50	7·40	0·285	0·156
Northern wheatgrass *(Agropyron dasystachyum)*							
Leaf	3	May 30	16·06	26·65	6·80	0·300	0·210
Late leaf	2	June 23	11·82	33·48	6·55	0·350	0·160
Leaf, cured	2	Oct. 18	4·16	36·66	9·49	0·540	0·070
Rough fescue *(Festuca scabrella)*							
Medium leaf	3	June 16	12·00	30·26	10·14	0·300	0·182
Late leaf	3	July 21	8·83	31·75	10·06	0·295	0·129
Flower	2	June 26	8·58	33·15	11·42	0·185	0·180

The three species in Table 26 are from Shortgrass, Mixed and Submontane Prairie respectively. It is evident that marked changes occur in the composition of the foliage of all three species as the season progresses, even when no culm production takes place. The changes are similar to those occurring in normal growth development. Crude protein and phosphorus decrease while crude fibre increases.

Comparison of material in flower with that in leaf at approximately the same date indicates that both the development of culms and increasing maturity of the foliage are concerned in the seasonal variation in chemical composition.

The results outlined above are in general agreement with those of other workers. It has been found that the chemical composition of grass foliage changes greatly during the season, while the development of culms affects composition to a marked extent.

The data obtained in the present study indicate that grass which remains in the leaf stage throughout the season has a more desirable chemical composition than when culm formation occurs. However, the lower yields of the former are likely to offset this advantage to a large extent in the drier grassland zones at least.

EFFECTS OF CERTAIN FACTORS ON CHEMICAL COMPOSITION OF NATIVE FORAGES

Effects of Climate

Sampling of the principal native forages at the Manyberries Station during the period 1929 to 1938 afforded an opportunity for study of the effects of variations in climate on chemical composition. Samples of each of the main species were collected at the same sites and in similar growth stages each year during most of this period.

Under the dry conditions prevailing in the Manyberries area, plant growth is limited mainly by the supply of available moisture, as shown by the close relationship between precipitation, evaporation and native forage yields (8). Pertinent climatic data for the period are presented in Table 27.

TABLE 27.—PRECIPITATION AND EVAPORATION IN INCHES AT THE MANYBERRIES RANGE STATION, 1929-1938

Year	Precipitation		Evaporation	P/E Ratio[1]	Category
	Total	Apr.-Sept.	May-Sept.		
1929	9·96	6·50	32·99	0·197	Medium dry.
1930	13·40	8·40	33·76	0·249	" "
1931	10·20	7·29	33·19	0·220	" "
1932	12·40	10·45	26·56	0·393	"Favourable".
1933	11·20	8·52	36·55	0·233	Medium dry.
1934	11·20	6·90	33·05	0·209	" "
1935	8·41	5·43	32·87	0·165	" "
1936	7·19	4·25	38·98	0·109	"Very dry".
1937	10·30	5·82	30·43	0·191	Medium dry.
1938	12·70	9·00	26·77	0·336	"Favourable".
Av.	10·67	7·26	32·52	0·230	

[1] Ratio of precipitation for Apr.-Sept. to evaporation, May-Sept.

While there was considerable variation in conditions affecting plant growth, most of the seasons tended to be fairly similar. Only in 1932, 1936 and 1938 was there marked deviation from the group average. To facilitate analysis of the data, the years have been grouped into three classes as shown in Table 27. Actually, the whole period was one of comparative drought, and the "medium dry" years included several seasons such as 1935 and 1937 during which conditions for plant growth were almost as unfavourable as in 1936.

Data for samples of the five major grasses collected at the Manyberries site in the leaf, flower and seed stages are grouped according to the above division of years. Since few samples were available for 1936, comparison was confined to the groups of "favourable" and "medium dry" years. The data are summarized in Table 28.

TABLE 28.—EFFECTS OF CLIMATE ON CHEMICAL COMPOSITION OF SHORTGRASS PRAIRIE GRASSES—1929-1938 INCLUDED

Constituent	Average Chemical Composition in "Medium Dry" and "Favourable" Years								
	Leaf Stage			Flower Stage			Seed Stage		
	Med. Dry	Favourable	Diff. in P.C.	Med. Dry	Favourable	Diff. in P.C.	Med. Dry	Favourable	Diff. in P.C.
Crude protein	18·8	18·8	....	10·0	10·7	+ 6·8	7·7	7·6	....
Crude fibre	24·3	26·3	+ 8·2	32·4	35·7	+10·0	32·7	34·7	+ 6·0
Total ash	8·95	9·96	+11·3	6·32	7·18	+13·6	6·26	7·24	+15·6
Calcium	0·402	0·410	....	0·278	0·261	− 6·1	0·333	0·270	−19·0
Phosphorus	0·251	0·278	+10·8	0·176	0·234	+31·**	0·130	0·153	+17·7*

* Significant, beyond 5 per cent point.
** Highly significant difference, beyond 1 per cent point.

The only significant differences are those for the increase of phosphorus content in the flowering and seed samples during the "favourable" years. The tendency for the percentage of crude fibre and total ash to be higher in the "favourable" seasons is fairly marked in each growth stage and may represent a real trend, though not significant statistically in the samples studied.

Culm production was much greater in favourable than in dry years. According to the data of Table 25 there would be a tendency for the content of crude fibre to increase and that of protein, total ash and phosphorus to decrease with an increase in the proportion of culms. Apparently the greater vigour of growth and delay in curing due to better moisture conditions offset

this effect in the case of protein and more than offset it for phosphorus and possibly total ash.

The literature indicates that the phosphorus content of forage plants usually is lessened under drought conditions. However, Scott (39) in Montana found no marked effect of precipitation on either the phosphorus or calcium content of native forage species. In Oklahoma, Daniel and Harper (15) reported that the phosphorus content of native grasses was greater in wet years than in dry ones, while the trend for calcium was just the opposite. A similar trend has been noted in New Zealand (1) and in Australia (36). The same tendency is evident in some of the data in the present study, e.g., Table 28, material in the seed stage.

In pastures of more humid areas, where the grass usually is kept in the leaf stage, decreases of protein as well as of phosphorus often occur under dry conditions (1, 21). The percentage of protein does not seem to be affected commonly in this way in the herbage of grazing lands in drier regions.

Effects of Soil

There is wide variation in the soils of the native pasture areas of southern Alberta and Saskatchewan, four zonal types and a wide range of texture classes being included. However, many of the major forage species are confined largely to one soil zone and often to soils of certain textures within the zone. For instance, common speargrass is abundant mainly in the Brown and Dark Brown Soil zones and is confined largely to soils not finer than loams. Thus the occurrence of the same species on widely differing soil types is not so common as might be supposed.

Some study was made of the composition of certain grasses on normal prairie soils as compared with the same species growing on adjacent sandhill areas. In this case, climatic conditions were similar at the two sites and the only major habitat difference was that of soil type. Nine paired samples of grasses were obtained on such sites. These included samples of each of three species in the leaf, flowering and cured stages of growth. The results are presented in Table 29.

TABLE 29.—EFFECT OF SOIL TYPE ON CHEMICAL COMPOSITION OF THREE COMMON PRAIRIE GRASSES[1]

Soil Type	Chemical Composition in Per Cent				
	Crude Protein	Crude Fibre	Total Ash	Calcium	Phosphorus
Brown loam	12·2	30·1	7·04	0·291	0·216
Sand	11·8	29·6	6·47	0·327	0·162
Difference	− 0·4	− 0·5	−0·57	+0·036	−0·054

Minimum significant difference for phosphorus = 0·050%.

[1] Junegrass, common speargrass and northern wheatgrass.

A significant difference in composition of forages on the two soil types occurred only in the case of phosphorus.

Studies by other workers do not indicate the presence of a simple relationship between the composition of forage plants and the soil upon which they grow. However, it is apparent that much more study is needed on this problem.

Fraps and Fudge (18) in Texas found correlations between the percentage of protein, calcium and phosphorus in the soil and in pasture plants. However, the relationship held only for certain species and some soil types. In Oklahoma, Daniel and Harper (14) reported a slight correlation between the calcium and

phosphorus content of soils and of the native grasses growing on them. However, these authors stress the complexity of the relationship and conclude that "the study of a single plant food element in the soil will not give an accurate indication as to the amount of that element which will be found in the plant."

Another important but less direct effect of soil type on the chemical composition of pasture herbage is that due to differences in botanical composition. In sandhill areas, the forage includes both species common to the whole prairie region and others confined largely to sandy soils. Some of the latter group, including sandgrass and sand dropseed are inferior in chemical composition to most species of normal prairie. The crude fibre content is higher and the percentage of protein, fat and phosphorus is lower than in typical prairie forages.

Effects of Commercial Fertilizers

The effect of several commercial fertilizers on the composition of native herbage was tested at the Manyberries Experiment Station. Two sites were used, one on fine sandy loam, the other on a silt loam alluvial soil. The vegetation of the first site was composed mainly of common speargrass and grama grass, while western wheatgrass dominated on the second. The fertilizer was applied as a top dressing in early spring, at an average rate of 150 pounds per acre. From seven to nine replicates were used for each treatment.

In the fall, forage samples were collected from each individual plot and the content of protein, phosphorus and calcium determined. The results are presented in Table 30.

TABLE 30.—EFFECT OF FERTILIZERS ON CHEMICAL COMPOSITION OF SHORTGRASS PRAIRIE FORAGE, MANYBERRIES, 1930

Constituent	Site	Composition in Per Cent for Different Treatments					Minimum Sig. Diff.
		Ammonium Phosphate	Sodium Nitrate	Ammonium Sulphate	Super-phosphate	Unfertilized Check	
Crude protein	1	7·9	8·2	8·3	6·7	7·1	1·2
Crude protein	2	6·0	6·2	6·3	4·9	5·1	0·44
Phosphorus	1	0·188	0·131	0·148	0·157	0·135	0·017
Phosphorus	2	0·096	0·070	0·079	0·080	0·070	0·010

There were no significant differences in protein content at site one, although the increases for ammonium sulphate and sodium nitrate approached significance. In this connection it should be noted that forage yields were increased significantly by all of the nitrogenous fertilizers applied, the increases varying from 32 to 36 per cent. Thus the absolute amount of protein produced on each plot was increased appreciably even in cases where the percentage in the plants was not altered significantly. At site two, all three nitrogenous fertilizers raised the percentage of protein significantly.

The phosphorus content of the forage at each site was increased significantly by both ammonium phosphate and superphosphate. Ammonium sulphate increased the percentage of phosphorus also, but not quite to the point of significance.

Differences in results at the two sites are in keeping with the nature of the soils. The data given in Table 3, show that both nitrogen and available phosphorus are present in higher amounts in the sandy loam upland soil than in the silt loam. This would account probably for the greater response to nitrogenous fertilizers at site two. With phosphorus, the data do not indicate any differential response due to differences in the two soils.

The experiment described above was conducted in 1930. Similar results were obtained with tests made in 1931. However, in 1931, sodium nitrate increased the protein content of the forage significantly at site one.

Climatic conditions during 1930 and 1931 were about average for the Manyberries area (see Table 27). Hence the results of the fertilizer tests may be considered fairly typical of what might be expected over a longer period.

A few trials of fertilizer application on Submontane Prairie in the Cypress Hills area yielded striking results. The vegetation in this case consisted mainly of rough fescue and the soil was a shallow black, gravelly loam.

The results of top dressing with commercial fertilizers at the rate of 150 pounds per acre were as follows:—

(1) The phosphorus content of the forage was increased 140 per cent by ammonium phosphate and 97 per cent by superphosphate.

(2) Protein content was affected less, being increased 19 per cent by ammonium phosphate and 18 per cent by ammonium sulphate.

The soil type on which this test was conducted is generally low in available phosphorus, being inferior to normal soils of the Brown zone in this regard (50).

There are many references in the literature to the effects of commercial fertilizers on the composition of pasture plants in relatively humid areas. Generally, applications of nitrogen and phosphorus result in increases in the percentage of protein and phosphorus in the forage. The effects are most marked on soils of low fertility.

Fewer studies of this nature have been made with pastures in drier regions. Richardson and co-workers (36) in Australia obtained increases in the phosphorus content of native forage plants due to applications of phosphatic fertilizers on soils deficient in this mineral. Similar results in South Africa have been reported by Henrici (24). In Montana, Willis and Harrington (48) tested the application of triple superphosphate to dry land plots of crested wheatgrass, brome grass and native prairie. Marked increases in the phosphorus content of the herbage were obtained in all three cases, the response of the native grasses being greater than that of the cultivated species.

CHEMICAL COMPOSITION IN RELATION TO LIVESTOCK NUTRITION AND GRAZING PRACTICES

The chemical composition of a large number of native forage species has been discussed in preceding sections of this publication. In the following portion, the relation of the composition of these plants to livestock nutrition and grazing practices in southern Saskatchewan and Alberta will be treated briefly.

Chemical Composition and Nutritive Value

The ultimate use of range forage is as feed for livestock, hence it is nutritive value rather than chemical composition which is of prime importance. However, determination of the nutritive value of any feed involves actual tests with livestock and is too costly and laborious a process to be used on many species. Thus, it is necessary to rely largely on chemical analyses, together with the results of such feeding trials as may be made.

The analyses presented in this study were made by the regular "feeding stuffs" procedure which has been standard for such work. In this method, nitrogen, ether extract (fats, waxes, etc.), total ash and crude fibre are determined. The crude protein content is calculated from the percentage of nitrogen by multiplying the latter by a standard factor (6·25). The difference between the combined total of crude protein, crude fibre, ether extract and total ash and one hundred per cent represents the nitrogen-free extract. This fraction consists of a variety of carbohydrates including starches, sugars and cellulose.

The validity of the division of the carbohydrate fraction into crude fibre and nitrogen-free extract has been questioned by Maynard (29), Norman (34), Crampton and co-workers (10, 11) and others. Formerly it was assumed

generally that the crude fibre content of any feed was largely indigestible. Actually it has been shown that the crude fibre content of young grass may be as digestible as the nitrogen-free extract (10). The latter constituent is itself a conglomeration of substances, the relative amounts and digestibility of which may vary greatly during growth development.

Recent studies have shown that lignin is of great importance in connection with the nutritive value of forages (10, 29). Lignin is low in digestibility, and its presence affects the digestibility of other constituents, especially cellulose. Revised procedures for analysis have been suggested in which the carbohydrate fraction is divided into cellulose, lignin and "other carbohydrates". While such methods have not yet been perfected, analyses made in this manner by Crampton and Forshaw (11) in Quebec and Patton and Gieseker (35) in Montana have yielded results more in accord with the results of actual feeding trials than those obtained by the regular feeding stuffs analysis.

In view of the above facts, it is evident that the results of chemical analyses must be interpreted with some caution. Formerly it was assumed that high feeding value was associated mainly with high protein and low crude fibre content but it is evident that this assumption cannot be regarded as entirely valid for immature plants, although it still applies fairly well to cured forages. In young grass the crude fibre fraction is relatively digestible, and the high nutritive value may be due as much to the presence of certain carbohydrates as to high protein content.

The standard chemical analyses do provide a comparative measure for different forages and serve to show what constituents are deficient or present in excess. The determination of both phosphorus and calcium content in the present study added greatly to the value of the analyses.

No digestibility trials have been made with range forages in Western Canada, but a few such studies have been made in the United States. Most applicable to the present study are the investigations of Christensen and Hopper (9) in North Dakota, and Sotola (40, 41) and Burkitt (4) in the state of Washington. Christensen and Hopper fed native prairie hay cut in early April, July and October to steers. This hay contained a high percentage of common speargrass *(Stipa comata)*. The October and April cuttings consisted of cured forage, and the April lot had stood out over winter. It was found that the digestibility of all constituents was highest in the July cutting and lower in the other two. The palatability of the July cuttings proved to be higher than that of the April or October cuttings, and greater amounts of the former were eaten.

Sotola fed samples of crested wheatgrass cut in the early leaf, late leaf and flowering stages to sheep. The percentage of total digestible nutrients was found to be similar in the two leaf stages but much lower in the flowering samples. The percentage of digestible protein and fat declined more rapidly than that of crude fibre and nitrogen-free extract. A similar experiment using common brome grass gave comparable results but indicated that brome retains high nutritive value to a more advanced stage than does crested wheatgrass.

Burkitt tested the feeding value of beardless wheatgrass *(Agropyron inerme)* in early leaf, late leaf and flowering stages by a technique similar to that of Sotola. The results showed that the greatest consumption of feed and best gains were made by the animals fed on grass in the early leaf stage. The digestibility of all nutrients decreased with growth development.

The studies mentioned above are of particular importance in the present case because of the nature of the forages studied. The North Dakota prairie hay was similar in composition to the forage of Mixed Prairie areas in Western Canada. Crested wheatgrass, studied by Sotola, has become an important range species due to its wide use in reseeding abandoned fields and depleted pastures, while common brome grass is used for the same purpose to a lesser extent.

Beardless wheatgrass is not common in the Prairie Provinces but is similar in chemical composition and growth development to many of the principal prairie grasses.

All of these digestibility trials agreed in finding that the nutritive value of range grasses is highest in the leaf stage and declines with growth development, reaching a minimum value in the cured stage. Christensen and Hopper found the digestibility of the forage which had stood out over winter to be slightly higher than that of the October cutting. However, studies made in California (23) indicate that a further decline in feeding value may occur in cured forage which stands out over winter. The trend in winter probably depends on climatic conditions; rainfall and wet snow being the principal leaching agents.

Palatability of Forage in Relation to Livestock Nutrition

It is obvious that palatability is of prime importance in connection with the grazing value of any species. Desirable chemical composition is of little value unless a species is eaten readily by livestock.

Studies of the relative palatability of the common species of the Shortgrass Prairie have been made since 1928. The palatability of species in other range zones has been investigated in more recent years. Comparative ratings have been made for the amounts of different species eaten in various growth stages, at different times of the year and under various intensities of grazing. In the case of the Shortgrass Prairie species, enough studies have been made to give a fairly complete picture of the relative palatability of plants in this zone. Palatability is influenced by a number of factors, including class of livestock, intensity of grazing, growth stage of the plants, time of year and relative abundance of other desirable species. It follows that palatability ratings can be regarded as approximations from which marked deviations undoubtedly will occur. Data for the Shortgrass Prairie species are presented in Table 31.

TABLE 31.—RELATIVE PALATABILITY TO CATTLE OF PRINCIPAL NATIVE SPECIES OF SHORTGRASS PRAIRIE

(1) Eaten Readily	(2) Eaten Fairly Readily	(3) Eaten Slightly	(4) Eaten Rarely or not at all
Common speargrass	Plains reedgrass	Prairie muhlenbergia	Dwarf everlasting.
Grama grass	Saltgrass	Wild barley	Dwarf phlox.
Western wheatgrass	Alkali cordgrass	Involute-leaved sedge	Broom weed.
Junegrass	Russian thistle	Pasture sage	Cactus (all species).
Dwarf bluegrass		Sagebrush	Little clubmoss.
Niggerwool			
Winter fat			
Salt sage			

Most of the grasses and a few broad-leaved species are eaten readily by cattle and other classes of live stock. However, there are seasonal differences among even the favoured species. Grama grass usually is eaten less than speargrass or wheatgrass during the spring and summer months, but it is taken readily in fall and winter. Dwarf bluegrass is eaten mainly in spring while still green and is grazed very little after the middle of June.

Many of the plants of group two and some in group three are eaten readily enough at certain times of the year. Saltgrass and alkali cordgrass are grazed

well in late fall and winter, but are avoided earlier in the season. Pasture sage is eaten fairly readily in winter, although rarely touched by cattle in summer. Sagebrush is grazed considerably in winter. Sheep eat much more of the sages and of most other broad-leaved species than do cattle. Russian thistle is eaten readily when green and tender but less when mature and spiny.

While most of the highly palatable species contain high percentages of desirable nutrients, there are unpalatable plants such as certain native legumes and broom weed which are rich in desirable constituents also. Even plants poisonous to livestock may be well supplied with nutrient elements and may be eaten on this account. Succulence appears to be an important factor affecting palatability. It was observed that several of the broad-leaved species, including salt sage and winter fat, are grazed much more in the fall after the grasses have cured and when these non-grasses are still comparatively green.

The data obtained for plants in the other zones are less complete than those for the Shortgrass Prairie. Approximate ratings for the principal species are presented in Table 32.

TABLE 32.—RELATIVE PALATABILITY TO CATTLE OF PRINCIPAL SPECIES OF OTHER PRAIRIE ZONES[1]

(1) Eaten Readily	(2) Eaten Fairly Readily	(3) Eaten Slightly	(4) Eaten Rarely or not at all
Short-awned porcupine grass	Sand dropseed	Sandgrass	Slender sage.
Green speargrass	Wild oatgrasses	Goldenrods (most species	Prairie goldenrod.
Northern wheatgrass	Willows (most species)	Wild lupines	Sandhill rose.
Awned wheatgrass		American hedysarum	Lance-leaved psoralea.
Slender wheatgrass		Wild licorice	
Rough fescue		Western snowberry	
Bromes (all species)		Chokecherry	
Indian ricegrass		Shrubby cinquefoil	
		Sandbar willow	
		Aspen poplar	

[1] Includes species of Mixed and Submontane Prairie as well as sandhill vegetation.

In general, the grasses of all prairie zones are medium to high in palatability, while many of the broad-leaved forages are less desirable. Virtually all the species listed in class two are eaten readily in late fall and winter but to a lesser extent earlier in the season.

Information regarding the relative palatability of forest range species is at present very incomplete and no attempt is made here to rate these plants. Results of studies made to date indicate that most of the grasses and many of the forbs and shrubs of timber pastures are eaten readily by all classes of live stock.

Data from feeding trials have indicated the importance of palatability as a factor affecting the amount of forage consumed and the gains made by live stock. In the tests by Christensen and Hopper and by Burkitt, described in a previous section, the amounts of the various feeds consumed decreased significantly in later growth stages. Undoubtedly this smaller intake of feed was partially responsible for the declines noted in the gains of the test animals. To what extent the total dry matter intake of animals grazing on the range is affected by the degree of forage maturity is not known at present.

Seasonal Changes in Chemical Composition in Relation to Gains Made by Livestock

Data presented in previous sections have shown that there is a marked seasonal decline in the percentage of certain nutrient elements in range forage plants. In addition, the digestibility of most fractions decreases as growth development proceeds. The cobined effect is to furnish range livestock with feed high in digestible protein, carbohydrates and minerals in spring and early summer. There is a marked decline in feed quality during the remainder of the year. The reaction of the animals to this seasonal variation in quality of forage is of great importance to the producer of livestock.

Studies have been made at the Manyberries Range Station (46) of the gains made by different ages and classes of Hereford cattle on moderately grazed native pastures. The data for one and two year old steers are presented in Table 33.

TABLE 33.—AVERAGE GAINS IN WEIGHT OF CATTLE ON SHORTGRASS PRAIRIE RANGE AT MANYBERRIES, ALBERTA

Class of Cattle	Gain in Weight in Pounds[1]			
	April 1–June 15	June 16–September 1	September 2–November 15	Total
Yearling steers	131	138	46	315
Two year old steers	145	159	52	356

[1] The data are for the 8-year period, 1929 to 1936 inclusive.

Highest gains were made during the months of May, June, July and August. Gains after the end of September were slight.

The rate of gain is related evidently to the quality of the available forage. In May, June and July there is plenty of forage in the earlier growth stages, while even in August some of the later species are more or less green. By September all forage usually is cured. The fact that higher gains were not made in April and May appears to be due partly to the condition of the experimental animals at the start of the grazing season. These cattle were wintered on the range with a minimum of extra feed, and apparently required a few weeks on high quality forage before starting to make rapid gains. Another factor of importance in this regard is the lack of an adequate volume of desirable forage early in the season.

Similar trends for seasonal gains in cattle have been reported from other western range areas. Sarvis (37) in North Dakota studied the gains of cattle on native pasture over a twenty-year period. The average gains for two year old steers on moderately grazed fields were: May—53, June—107, July—69, August—56 and September—38 pounds. In October there was a loss of 3 pounds, making an average seasonal gain of 320 pounds.

It is evident from the above data that the gains made by livestock on the range are determined not only by the quantity but also by the quality of the forage available. High rates of gain cannot be expected from forage of low nutritive value even though stock may have access to an abundance of it. On the other hand, large and economical gains can be made during the spring and summer months provided that adequate supplies of forage and water are available.

The marked seasonal decline which occurs in the nutritive value of range forage and in the gains made by livestock grazing on it is of great importance in regard to the time of marketing, particularly for cattle. Since the rate of gain after the end of August is very low, there is little advantage in holding beef

animals on pasture after that time unless steps are taken to produce added gains. This may be done either by the supplemental feeding of grain to cattle on the range, or by moving them onto green forage as found on irrigated pasture or "cover crops" on grain fields. By means of either of these two practices it is possible not only to increase the weight of the animals but also to improve their finish.

The Chemical Composition of Forages in Relation to Grazing Practices

Since the health and proper development of livestock depends to such an extent on the composition of their feed, it follows that this factor is one to be considered in range management. This is true particularly because of the great variations which occur in the chemical composition and nutritive value of prairie forage during different seasons of the year.

A knowledge of the chemical composition of the main species of an area can be used to good advantage in planning the best utilization of the forage. Some points of practical importance in this regard are as follows:—

1. Pastures which are to be grazed early in the spring should not be cropped closely during the previous fall. The young grass of early spring is not a balanced feed, being more of a watered concentrate. Mixed with cured forage, it makes excellent feed, while eaten alone it is apt to produce scouring in stock with consequent poor gains. In addition, when no old growth is available, stock tend to wander excessively in order to obtain enough bulk. This excessive travelling is harmful to animals and pasture alike.

2. Pastures containing a mixture of species usually are preferable to those composed of pure stands of one species. The various native and introduced pasture forages vary considerably in chemical composition, palatability and growth development. Hence, a mixed stand usually will produce a more desirable type of feed throughout the whole season. For example, in the Shortgrass Prairie, early species such as Junegrass and niggerwool are valuable especially for early spring pasture, while speargrass and western wheatgrass are excellent for late spring and summer. Grama grass, which is later in growth development than any of these is of little use for spring grazing but makes good feed for late summer and fall. Some of the broad-leaved forage plants, such as winter fat and salt sage remain green for a period in early fall after the grasses have cured and are eaten extensively at that time. In winter, species such as pasture sage which are unpalatable during the summer are grazed considerably and provide valuable nutrients.

3. Where pastures dominated by one species do occur, every effort should be made to utilize them at the time of year when that species is relatively most valuable as feed. This problem has arisen in some prairie regions where large areas of abandoned farm land and depleted native pasture have been seeded to crested wheatgrass. This species begins growth earlier in the spring than most native forages and often makes additional green growth in the fall when the latter are cured. However, it tends to become dormant and less palatable in mid-summer. It is suited best for spring and fall grazing and should be used in that manner if possible. Where areas of native pasture are available, a rotation with the latter used in midsummer gives excellent results.

4. The relative feeding value of different classes of forage is a factor worth consideration in choosing areas for winter grazing. Many of the broad-leaved herbs and shrubs are higher in nutritive value when in the cured stage than are the grasses. In addition, species such as pasture sage and sagebrush which are relatively unpalatable in the summer are utilized to a considerable extent in the winter. McCall (31) at Pullman, Washington, found that a mixture of 10 per cent of sagebrush and other non-grasses with 90 per cent of bluebunch wheatgrass was more palatable, digestible and nutritious for lambs than was cured grass alone.

It follows from the above facts that, other factors being equal, an area containing a considerable proportion of broad-leaved forages is preferable for winter pasture to one containing grass only. Fortunately, areas of rough topography such as are desirable for winter grazing because of the shelter provided often contain considerable broad-leaved forage. Winterfat, salt sage, willows, pasture sage and some sagebrush are highly desirable on a winter range.

5. In view of the decline in nutrient content and digestibility of the native forage as it matures, the question of supplemental winter feeding in the range areas merits consideration. The data available indicate that digestible protein and total digestible nutrients as well as phosphorus may be deficient in the cured range forage. While dry stock may not suffer from such a diet, it is apt to be inadequate for proper nutrition of cows in calf or ewes carrying lambs. For such animals, supplemental feeding with hay of good quality or a concentrate such as grain or oilmeal may be desirable in order to remedy the deficiencies of the cured grass. The beneficial results obtained by ranchers who are following this practice indicate the value of supplemental feeding where this can be done economically.

FIGURE 11.—Good winter range in the Shortgrass Prairie zone. Plenty of forage, mainly western wheatgrass with some sagebrush, occurs on the flat, while shelter is provided by the rougher lands in the background.

Feeding low quality hay to cattle on winter pasture will do little to improve their nutrition, as such hay is low in the very constituents which are deficient in cured grass. This is true particularly of native meadow hay cut in a late growth stage.

Mineral Deficiencies and Supplements

Many minerals, including calcium, phosphorus, sodium, chlorine, magnesium, potassium and traces of iron, iodine and cobalt are required for the proper

nutrition of livestock. Calcium and phosphorus are the constituents required in greatest amount and apart from the elements contained in common salt are the two most frequently deficient in the diet of grazing animals.

Numerous studies of the chemical composition of forages have shown that calcium, while frequently deficient in humid areas, is present usually in sufficient amounts in the forage of drier regions. Phosphorus, on the other hand, often is deficient in the feeds of dry areas. A severe phosphorus deficiency has been found to be widespread in South Africa. In North America, deficiencies have been reported from Texas, New Mexico, California, Montana and Manitoba while the forage of several other areas has been found to be low in phosphorus at certain periods.

Various estimates have been made of the amounts of calcium and phosphorus needed by grazing animals and hence in the forage upon which they feed. Watkins (47) concluded from his own studies in New Mexico and from those of other workers in various parts of the world that 0·250 per cent of calcium and 0·120 per cent of phosphorus is the minimum required by range cattle. The average phosphorus content of the forage of areas deficient in that mineral was calculated by Fraps and Fudge (18) to be 0·082 per cent while that of normal areas was 0·170 per cent. Most investigators recognize a difference between the amount of phosphorus necessary to prevent obvious deficiency symptoms and that needed for maximum development of the animal. A further source of variation in estimating requirements of calcium and phosphorus is that these vary considerably in different classes and ages of livestock. Generally, young animals and pregnant or lactating females have the highest requirements. It is obvious that no one level of calcium or phosphorus can be set as a minimum for all classes of livestock. Fraps and Fudge (18) have worked out approximate standards which are useful as a guide in this regard.

Data presented in the present publication show that the content of calcium and phosphorus, like that of other constituents, varies considerably in different growth stages of range forages. Any assessment of the status of these species with regard to minerals must take into account such seasonal changes. Data for the calcium and phosphorus content of the five principal grasses of the Shortgrass Prairie in various growth stages are presented in Table 34. The rating of each stage according to the Fraps and Fudge standard is shown.

TABLE 34.—CALCIUM AND PHOSPHORUS CONTENT OF PRINCIPAL GRASSES OF SHORTGRASS PRAIRIE

Growth Stage	Average Date of Collection	Percentage of Calcium	Fraps and Fudge Rating	Percentage of Phosphorus	Fraps and Fudge Rating
Leaf	May 25	0·390	Good	0·252	Fair.
Sheath	June 14	0·274	Fair	0·206	Fair.
Flower	June 26	0·277	Fair	0·181	Fair.
Medium seed	July 17	0·291	Fair	0·134	Deficient.
Cured	Sept. 28	0·337	Good	0·084	Deficient.
After winter exposure	April 8	0·361	Good	0·062	Very deficient.

It is evident that these grasses are well supplied with calcium in virtually all stages, and that there is no long period in the year when the content of this mineral could be considered deficient. The phosphorus content is much less satisfactory, becoming low by the time the seed stage is reached, and being definitely deficient in the cured forage. The calcium-phosphorus ratio, while

quite low in the earlier growth stages, is fairly high in the cured forage, and this may be regarded as tending to intensify the effects of the low percentage of phosphorus.

A similar condition holds true for most of the forages of the other range zones. While some of the broad-leaved species are higher in phosphorus than the grasses, their content of this mineral usually is low when in the cured stage of development.

It would appear that in general, the native forages of southern Saskatchewan and Alberta have sufficient calcium for grazing animals. With phosphorus the situation is quite different. This mineral, while present in fair amounts in the earlier growth stages, is deficient in the cured forage of most species. The seasonal variation in phosphorus content of forage in the Shortgrass Prairie area is indicated in Figure 12.

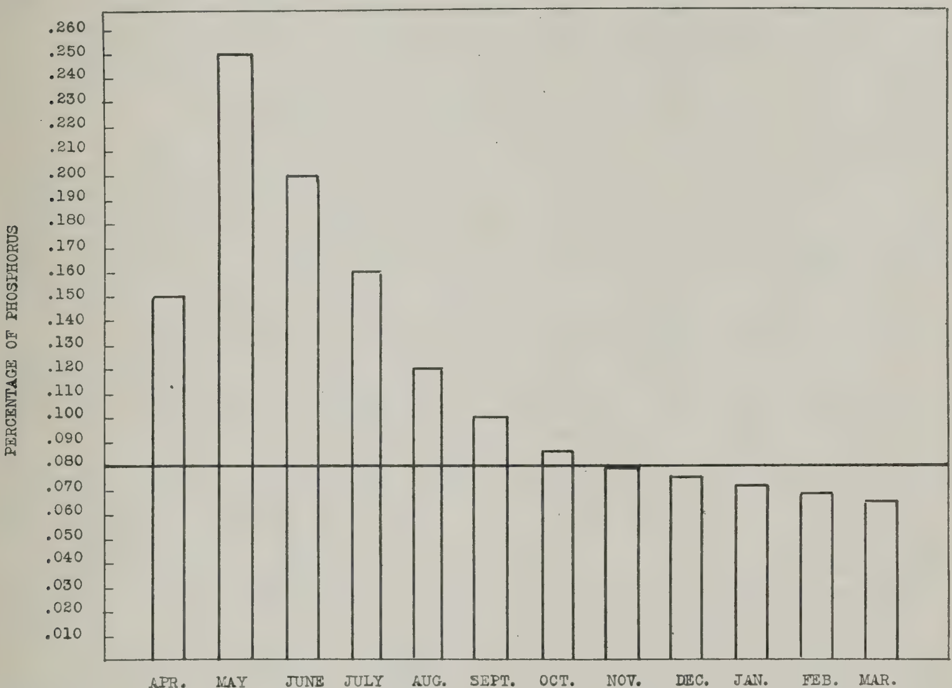

FIGURE 12.—Variation in phosphorus content of Shortgrass Prairie forage throughout the year. Horinzontal line at .080 per cent indicates a definite deficiency for range livestock while anything below 0.120 per cent is considered to be low.

These findings are of particular significance in the southern part of the two provinces where livestock are grazed out during the winter. In the Submontane and Forest zones there is less winter grazing and the nutrition of the livestock depends primarily on the quality of the hay fed.

The phosphorus deficiency existing in the cured vegetation of the prairies is reflected in the condition of the livestock feeding on this forage. Severe deficiency diseases such as found in South Africa do not occur normally, but many milder symptoms of mineral deficiency are present. Depraved appetite among stock with consequent bone chewing has been reported from many localities, while cases of animals with urinary calculi (stones) have become increasingly common. It is thought that this latter condition is due in part, at least, to a lack of balance between phosphorus and calcium. Other ranchers have reported poor calf crops and reproductive troubles in livestock which appear to be associated with mineral deficiency.

This lack of phosphorus in the native forage could be remedied probably by the application of commercial fertilizers to the pastures, as indicated by data presented earlier in this publication. A cheaper and more practical way is to add a mineral supplement directly to the diet of the livestock. A suitable supplement for this purpose is monocalcium phosphate. In its commercial form this product contains about 18 per cent phosphorus and 15 per cent calcium. Bonemeal may be used also but its phosphorus content is slightly less than that of monocalcium phosphate while it contains about twice as much calcium. The higher calcium content of bonemeal usually is of no advantage since most range species are well supplied with this mineral. It may be a decided disadvantage where the calcium-phosphorus ratio of the forage is unduly high. This latter condition is common in cured range forage.

Monocalcium phosphate may be fed alone in troughs or mixed with the salt supplied to livestock. One pound of the phosphate to two pounds of salt is a suitable mixture in most cases, but the proportions may be altered as desired. Livestock will eat the mixture readily and it has been found that the consumption of salt often drops when monocalcium phosphate is available. The use of rock phosphate or superphosphate is not recommended as these substances may contain fluorine which is harmful to livestock.

A large number of stockmen in the area covered by this study are feeding a phosphorus supplement, usually monocalcium phosphate, to their livestock. Very few who once adopt this practice ever abandon it, since the results obtained leave little doubt as to the benefits to be derived. Larger calf and lamb crops, heavier calves and lambs, better condition of the stock in the spring and freedom from depraved appetite are some of the benefits reported. The frequency of cases of urinary calculi appears to be reduced in some districts.

The need for a mineral supplement is greatest in the late fall and winter when only cured forage is available in the pastures. However, the results obtained on some ranches indicate that feeding smaller amounts of phosphate during the remainder of the year may be beneficial in certain areas.

In zones where the native pastures are used mainly during the summer grazing season (April or May to October), the need for mineral supplements may not be so great. In certain areas, however, phosphorus may be deficient in the forage even during the summer. Deficiencies may occur also where live stock are wintered on low grade hay. Data presented earlier indicate that native slough hay often is low in phosphorus, particularly if cut late in the season. Many samples of such hay have been found to have a phosphorus content of only 0·110 per cent which may be regarded as a minimum requirement for dry animals and too low for pregnant females. Where animals are being fattened, the phosphorus requirements are high. Beeson and co-workers (2) in Idaho have reported that a phosphorus content of 0·180 per cent was required for best results in fattening steer calves.

The results obtained by feeding mineral supplements in other mineral-deficient areas of the world have indicated the value of this practice. In South Africa, diseased conditions of livestock resulting from a lack of phosphorus have been remedied. In New Mexico, Knox and Watkins (28) have reported several benefits from the feeding of phosphorus supplements. A smaller death loss in newborn calves, better calf crop, greater weight of calves and lambs at weaning, greater gains in weight by cattle and higher wool production from range ewes are the principal benefits. Similar results have been reported from other parts of the United States and from Australia.

This discussion has dealt with the mineral needs of range livestock feeding on pasture or native hay in the area covered by this study. Hence the emphasis has been placed on phosphorus, since it is the mineral most often deficient under these conditions. The mineral situation is not identical, however, in all parts of Western Canada or with all classes of livestock and all types of feed. In certain

areas other minerals, especially calcium and iodine may be deficient in pasture and hay crops. Certain classes of stock such as dairy cattle have particularly high mineral requirements and may require a supplement of both calcium and phosphorus. Livestock being fed considerable amounts of grain or other concentrates low in calcium and rich in phosphorus are likely to develop a calcium deficiency.

In cases where both calcium and phosphorus are needed, bonemeal gives very good results. Steamed bonemeal contains about 32 per cent of calcium and 15 per cent of phosphorus. Where calcium alone is needed, ground limestone is a satisfactory supplement. A deficiency of iodine may be remedied by feeding commercial iodized salt or by adding a solution of potassium iodide in water to ordinary salt.

The object in all cases should be to supply the minerals likely to be deficient in view of the composition of the feed being used and the requirements of the animals being fed.

SUMMARY AND CONCLUSIONS

The results of chemical analyses of slightly over one thousand samples, representing the principal native forage plants of southern Alberta and Saskatchewan are presented in this publication. The relation of these data to livestock production and grazing practices in the area is discussed.

The study was begun at the Dominion Range Experiment Station, Manyberries, Alberta in 1927, and has been conducted also at the Dominion Experimental Station, Swift Current, Saskatchewan since 1938.

The area included in the study corresponds roughly to that embraced by the Brown and Dark Brown Soil zones, along with certain additional areas in the Cypress Hills and Rocky Mountain Foothills.

The climate of the area is characterized generally by light and variable precipitation, a relatively high evaporation rate, great extremes of temperature, high and frequent winds and abundant sunshine. The driest region is that lying south of Medicine Hat, Alberta and precipitation increases east, north and west of this area.

The soils of the region belong mainly to the Brown and Dark Brown zones, but smaller areas of Shallow Black, Black and Grey Forest Soils occur. Very sandy soils are found in some portions, particularly in southwestern Saskatchewan.

The native vegetation of the study area consists mainly of Shortgrass and Mixed Prairie, but Submontane Prairie and both deciduous and coniferous forest occur in the Cypress Hills and Rocky Mountain Foothills. The sandhill areas have a characteristic plant cover which includes grassland, shrub and even patches of woodland.

In regard to technique, each sample was restricted to one species in one stage of development, and sampling was done in such a manner as to simulate grazing. In most cases samples were taken at definite sites, and the more important species were collected in each of several growth stages for a number of years. The species of the Shortgrass Prairie were studied most intensively and those of the forest areas least.

The chemical composition of the forages studied was found to change greatly during growth development. The young leafage is rich in protein and minerals and relatively low in crude fibre content. The percentage of protein, ether extract and phosphorus drops sharply from the leaf to the flowering stage and then declines more gradually until curing occurs. The content of crude fibre and nitrogen-free extract increases throughout growth development. A further decline in percentage of protein, ether extract and phosphorus as well as a slight drop in nitrogen-free extract occurs in cured forage which is exposed over winter.

This seasonal change in chemical composition is characteristic of all classes of native and introduced forages. It is most marked in the grasses of the Short-grass Prairie where curing of leafage begins fairly early in the summer.

The principal grasses of the three prairie zones are much alike in chemical composition. Sandhill grasses tend to be slightly lower in percentage of protein and phosphorus and higher in crude fibre than those of normal prairie soils. Broad-leaved forages of all zones are generally higher in protein and minerals and lower in crude fibre than the grasses.

Analyses of the principal grasses and sedges of native meadows indicate that these species compare favourably with upland species in nutrient content. However, there is a rapid decline in quality after the flowering stage is reached, particularly in the sedges. The data indicate the importance of early cutting of native meadow hay.

Analyses were made of samples of three commercially grown forages, namely created wheatgrass, common brome and slender wheatgrass. These species all tend to be slightly superior to the common native grasses in nutrient content in the earlier growth stages but not when in the cured condition.

Statistical analyses of the data indicate that the leaf and flowering stages are best for the comparative study of the chemical composition of different species, since the variability of most constituents is at a minimum in these stages. There is a strong positive correlation between protein and phosphorus. Crude protein and phosphorus are negatively associated with crude fibre and nitrogen-free extract. Statistically significant differences in the percentage of protein, crude fibre and phosphorus exist between most growth stages of the main prairie grasses.

Separate analyses of leafage and culms and of grass in the leaf stage at various times during the grazing season indicate that seasonal changes in chemical composition are due both to the development of flower stalks and to maturing of the leafage.

Samples of native grasses collected at the Manyberries Station during years differing considerably in precipitation revealed a significantly higher percentage of phosphorus in the flowering and seed stages of plants grown in the moister years.

The effects of soil type on the chemical composition of species were studied in the case of a loam compared to a very sandy soil in the same climatic region. The percentage of phosphorus was significantly lower in the samples grown on the sand, but the content of other constituents was not affected appreciably.

The effects of top dressing of commercial fertilizers on two types of Short-grass Prairie were studied. Significant increases in phosphorus content of the herbage resulted from applications of phosphatic fertilizers. Nitrogenous fertilizers gave consistent increases in protein content only on the vegetation of silt loam alluvial soils low in nitrogen.

Studies of the seasonal gains of range cattle at the Manyberries Station indicate that best gains are made in the early and midsummer period with very little gain after the end of September. These results are in accord with the seasonal decline in quality of the range forage and indicate the advisability of marketing grass cattle early in the fall unless supplementary feed can be supplied to maintain a high rate of gain.

In general, the native forage species studied appear to supply the requirements of range livestock reasonably well except in the matter of phosphorus. The content of this essential mineral is fairly high in the young grass, but declines greatly with growth development and is definitely deficient in the cured forage. The remedy for the deficiency thus created is the feeding of a phosphorus-rich supplement, such as monocalcium phosphate during the late fall, winter and early spring months. In some areas it may be advisable to feed some phosphorus the year round.

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APPENDIX

Common and Scientific Names of Plants Discussed in the Text

Common Name	*Scientific Name*
	A—Grasses, Sedges and Rushes
Alkali cordgrass	*Spartina gracilis* Trin.
Awned wheatgrass	*Agropyron trachycaulum var. unilaterale* (Cassidy) Malte
Awned sedge	*Carex atherodes* Spreng.
Baltic rush	*Juncus ater* Rydb.
Canada brome	*Bromus purgans* L.
Canada wild rye	*Elymus canadensis* L.
Canby's bluegrass	*Poa Canbyi* (Scribn) Piper.
Common brome	*Bromus inermis* Leyss.
Common speargrass	*Stipa comata* Trin. and Rup.
Crested wheatgrass	*Agropyron cristatum* (L) Beauv.
Dwarf bluegrass	*Poa secunda* Presl.
Fringed brome	*Bromus ciliatus* L.
Grama grass, blue grama	*Bouteloua gracilis* (H.B.K.) Lag.
Green speargrass	*Stipa viridula* Trin.
Hooker's oatgrass	*Avena Hookeri* Scribn.
Idaho fescue	*Festuca idahoensis* Elmer.
Indian rice	*Oryzopsis hymenoides* (R. and S.) Ricker.
Junegrass	*Koeleria cristata* Pers.
Little bluestem	*Andropogon scoparius* Michx.
Marsh reedgrass	*Calamagrostis canadensis* (Michx) Beauv.
Niggerwool	*Carex filifolia* Nutt.
Northern reedgrass	*Calamagrostis inexpansa* A. Gray.
Northern wheatgrass	*Agropyron dasystachyum* (Hook) Scribn.
Nuttall's alkali grass	*Puccinellia Nuttalliana* (Schultes) Hitchc.
Parry's oatgrass	*Danthonia Parryi* Scribn.
Pinegrass	*Calamagrostis rubescens* Buckl.
Plains reedgrass	*Calamagrostis montanensis* Scribn.
Prairie muhlenbergia	*Muhlenbergia cuspidata* (Torr) Rydb.
Purple oatgrass	*Schizachne purpurascens* (Torr) Swallen.
Reed canary grass	*Phalaris arundinacea* L.
Rough fescue	*Festuca scabrella* Torr.
Saltgrass, alkali grass	*Distichlis stricta* (Torr) Rydb.
Sandgrass	*Calamovilfa longifolia* (Hook) Scribn.
Sand dropseed	*Sporobolus cryptandrus* (Torr) A. Gray.
Short-awned porcupine grass	*Stipa spartea var. curtiseta* Hitchc.
Short-awned brome	*Bromus breviaristatus* Buckl.
Skyline bluegrass	*Poa Cusickii* Vasey.
Slender wheatgrass	*Agropyron trachycaulum* (Link) Malte.
Slough grass	*Beckmannia Syzigachne* (Steud) Fern.
Spangle top	*Fluminea festucacea* (Willd) Hitchc.
Spike rush	*Eleocharis palustris* (L) R. and S.
Tall mannagrass	*Glyceria grandis* S. Wats.
Three-square bulrush	*Scirpus americanus* Pers.
Tufted hairgrass	*Deschampsia caespitosa* (L) Beauv.
Water sedge	*Carex aquatilis* Whal.
Western wheatgrass	*Agropyron Smithii* Rydb.
Wild barley	*Hordeum jubatum* L.
Wild oatgrass	*Danthonia intermedia* Vasey

B—Forbs, Shrubs and Trees

American hedysarum	*Hedysarum americanum* (Michx) Britton.
American vetch	*Vicia americana* Muhl.
Ascending milk vetch	*Astragalus striatus* Nutt.
Aspen poplar	*Populus tremuloides* Michx.
Chokecherry	*Prunus melanocarpa* (A. Nels) Rydb.
Dwarf phlox	*Phlox Hoodii* Richards.
Greasewood	*Sarcobatus vermiculatus* (Hook) Torr.
Lance-leaved psoralea	*Psoralidium lanceolatum* (Pursh) Rydb.
Silvery lupine	*Lupinus argenteus* Pursh.
Narrow-leaved milk vetch	*Cnemidophacos pectinatus* (Hook) Rydb.
Northern bedstraw	*Galium boreale* L.
Pasture sage	*Artemisia frigida* Willd.
Prairie goldenrod	*Solidago dumetorum* Lunell.
Russian thistle	*Salsola Pestifer* A. Nels.
Sagebrush	*Artemisia cana* Pursh.
Salt sage	*Atriplex Nuttallii* S. Wats.
Sandbar willow	*Salix interior* Rowlee.
Sandhill rose	*Rosa Macounii* Greene.
Saskatoon bush	*Amelanchier alnifolia* Nutt.
Shrubby cinquefoil	*Dasiphora fruticosa* (L) Rydb.
Slender sage	*Artemisia gnaphalodes* Nutt.
Small-leaved everlasting	*Antennaria microphylla* Rydb.
Smooth aster	*Aster laevis* L.
Spreading homalobus	*Homalobus tenellus* (Pursh) Britton.
Two-grooved milk vetch	*Diholcos bisculcatus* (Hook) Rydb.
Veiny peavine	*Lathyrus venosus* Muhl.
Western sea blite	*Suaeda depressa* (Pursh) S. Wats.
Western snowberry	*Symphoricarpos occidentalis* Hook.
Wild geranium	*Geranium Richardsonii* Fisch and Trautv.
Wild licorice	*Glycyrrhiza lepidota* Nutt.
Winter fat	*Eurotia lanata* (Pursh) Moq.